Design of Visual Inspection Workstation for Ceramic Tiles

Prepared by:

Mohamed Zakaria
Student ID: 983-27-6769

Date Submitted:
April 08, 2008

California State University, Dominguez Hills
MSQA – Distance Learning
Human Factors in QA
QAS 515.41
Instructor: Mr. Jim Clauson

Scope

This paper will cover the process of designing a new and improved workstation for inspecting and sorting ceramic tiles in a ceramic tiles production facility. The paper will focus on the process related human factors which have direct effect on the return rate of mis-sorted (graded) tiles from the market and how these human factors can be taken into consideration in the new designed workstation to enhance the inspection process by reducing the return rate of mis-graded tiles and to avoid unsafe working conditions and unsafe work practices.

Background

Production of ceramic tiles is a huge process that starts with bulk raw materials in the form of solid particles and ends with a product in the form of a rectangular plate with various sizes and thicknesses. The tiles are produced with a glazed surface with different drawings and colors. Tiles are produced in pieces which are collected and packaged in carton boxes to be delivered to the end user.

Ceramic tiles are used for decorating floors and walls in residential and commercial buildings. This application requires the tiles from the same type, color and shape to be identical and to be free from any surface defects. To achieve such a goal, at the end of each production line, an inspection and sorting workstation is installed to perform a 100% inspection. This workstation is operated by an inspector or sorter as called in other countries.

The inspection process of ceramic tiles is done visually by the inspector without any tools. The inspector has to detect any surface defect on the tile while it is moving on the production line conveyor and he has to decide whether the tile is of grade “A” or grade “B”. For grade “B”, the inspector will put a mark on the tile to indicate its grade and to help the sorting machine to take grade “B” out of the production line to another packaging line. The inspection process is done while the tile is moving and it has a start point and an end point.

The detection of surface defects is totally relying on the inspector and that is why each inspector is qualified through a specific training program designed for that purpose. This extensive training program describes the different types of surface defects that could occur on each tile. The training program lasts for 6 months in which the inspector under training will observe and participate in the inspection process under the supervision of a senior inspector. After completion of training, the inspector has to pass a practical exam.

The inspection process is done at the end of the production line as previously mentioned just before the packaging station. The inspection workstation is usually provided with special lighting fit-outs.

Problem

The ceramic tiles inspection process is using the 100% inspection approach which obligates that each tile should pass the inspection with one of two grades, “A” or “B” in which the difference will come in the price. The challenge in that process requires visual concentration for a long period (Inspector working hours). As we previously described that the inspector should pass an extensive training program specially designed to tackle that challenge but without taking into consideration the human factors’ problems that could arise.

The problem occurred when the management of the ceramic tile factory under study detected an increase in the number of returned boxes labeled as grade “A” which included grade “B” tiles. That problem was found accompanied with another problem which is the reduced production rate due to the reduced inspection rate which created a buffer of ceramic tiles waiting for inspection.

That was the problem from the management and operation point of view but ergonomically there is another side to the problem or in other words, there is another understanding to the real problem. The actual problem can be illustrated in the following points:

1. The human errors that resulted in mis-grading “B” tiles to “A” tiles.
2. The reduced performance of inspectors.
3. The exposure of inspectors to visual problem such as eyestrain or visual fatigue which resulted in admission to ophthalmologist.

To tackle this problem, a problem solving approach was adopted to stand on what improvement could be done to tackle the three above mentioned areas. The problem solving approach used is the DMAIC improvement cycle which includes the following elements:

1. Define the problem
2. Measure
3. Analyze results
4. Improve
5. Control

That problem solving technique provides a logical and structural sequence which helps in following the PDSA Deming’s cycle.

Measure

In this stage it is very important to answer some questions that could give more clarity to the picture. Those questions are as follows:

1. The purpose of applying measurement
2. What needs to be measured?
3. When measurements should be done.

The purpose of applying measurement is to know the previous and current status of the three sides of the problem under study. By acquiring such knowledge, it is easy to define the improvement targets that should be achieved and to be considered while setting improvement plans and HFE corrective actions.

The process characteristics that need to be measured are the return rate of mis-graded tiles, the inspectors performance represented in their inspection rate and finally the number of admission to ophthalmologist. The first one will be calculated by dividing the number of returned tiles by 10,000 tiles over a certain period. The second will be calculated by dividing the number of inspected tiles per hour. Finaly the third is very clear as a count to the number of admission to ophthalmologist.

Those measurements should be done on a regular basis starting from now onwards to facilitate tracking improvement while applying the HFE countermeasures.

The measurements described above were captured in two points, one represent current situation and the other represent the 6 months back and the results were reported as follows:

	Current Results	Six Months Ago Results
Return rate of mis-graded tiles	303 tiles/10000 tiles	95 tiles/10000 tiles
Inspector performance	300 m2/day (around 3300 tile/day)	340 m2/day (around 3700 tile/day)
Number of admissions to ophthalmologist/inspector per month	1	0.3

The results tabled above are showing the result of the HFE problem which exists in the inspection process and since the inspection process is done manually through one inspector and the same workstation which did not change during the six months then it very important now to analyze the current workplace and its related human factors.

Analysis

This part of the paper is the most important part as it will focus on analyzing the workplace and its related human factors taking while focusing on the three sides of the problem in order to find the HFE root cause which could be tackled by an HFE countermeasure to eliminate the root cause.

The analysis will be divided into seven sections in which each section will cover one area of the problem.

1. Mis-Graded tiles:

   This problem is caused due to a human error in detecting the existing surface defects and passing it as grade "A" instead of detecting it as grade "B". before investigating the matter it is better to know that the surface defects which could be detected are generally of three types:

   - Difference in color.
   - Spot defects
   - Pattern defects

   By looking deeply in that problem, it was found that these types of surface defects might not be detected due to ***incorrect response to the visual stimuli*** or due to ***improper visual clarity*** which has different causes such as ***improper illumination***, ***incorrect visual field positioning*** and/or ***incorrect color perception***.

   The above mentioned causes require the workstation design to be analyzed and the inspector training procedures to be analyzed. This will be covered later in separate section.

2. Reduced Inspector Performance and their admission to ophthalmologist:

   While analyzing this problem, it was found that the inspector performance depend on three factors, the first factor is related to the ***monotonous working environment*** in which everything is repeated with very low variety which cause the inspector to feel bored which in turn makes the inspector complains of feeling fatigued and ask for more breaks than usual.

   The second factor is related to their ***complains of eyestrain*** which could happen due to their expended effort in focusing on the tiles, while it is

moving, from a distance that is different from the personal minimal resting distance of accommodation.

The third factor is related to the strain that could happen due to the ***overuse of neck movements*** which could reach 120 neck movements between left side and right side in one hour. Such movements could result in a ***neck tension syndrome*** which is a muscle related overuse disorder which can be defined as an irritation of the levator scapulae and trapezius group of muscles.

The above mentioned causes require the workstation design to be analyzed, the inspector's health monitoring and the work procedures to be analyzed. This will be covered later in separate section

3. Summarizing the different causes:

As a result of the first step in the analysis, some causes were found have direct effect on the occurrence of the three problems discovered in the ceramic tiles inspection process. Those causes and further analysis needed are summarized in the following table:

Problem	Causes	Further Analysis
Mis-graded tiles	**incorrect response to the visual stimuli**	**Training Procedures & Program**
	improper illumination	**Workstation Design**
	incorrect visual field positioning	
	incorrect color perception	
Reduced Inspector performance & Admission to ophthalmologist	**monotonous working environment**	**Working (operating) Procedures**
	complains of eyestrain	**Workstation Design Inspector's Health Monitoring**
	overuse of neck movements	

Further to the identified causes, it is very important to do some further analysis to find the root causes which will lead us to the HFE countermeasures that should be applied to achieve improvement and to eliminate the causes of the main problems.

4. Analysis of Training Procedures and Program

The ceramic tile and specifically its surface is considered the visual stimulus to which the inspector should react and choose one of two actions to be done, either to put a mark on it or not.

Surface defects could vary from one tile to the other and that is why the stimulus to which the inspector reacts cannot be predicted unless there is enough information, monitoring and sophisticated analysis to the tile manufacturing process parameters which should be communicated to the inspector on a real time basis which is not practical. Because of that, the training program which builds the qualification of inspectors should be analyzed to see if it is taking into consideration the choice reaction time and correctness or not in its assessment.

After looking into the training procedures and program, the following was found:

- The training program includes an assessment to the correctness of the inspector's inspection but still the tiles provided in the assessment are not arranged in a way that could provide all types of defects in different shapes, patterns and randomly.
- Due to production constraints, the inspector might be trained on single production line producing one type of products which makes the inspector get used to the tile inspected and react differently and slowly to other tiles.

5. Analysis of working conditions

The working conditions at the inspection workstation are different from other production stations on the same production line. It was found that working hours are different as the inspector has to work one hour and 30 minutes continuously and then 30 minutes in another light duty on the same production line in a packaging job and then goes for another one hour and 30 minutes.

It was found that the 90 minutes are long enough to create the monotonous environment for the inspector because he inspects more than 800 identical tiles in that duration which makes him feels bored.

6. Analysis of Inspector's Health Monitoring

The health or medical regular checkup was found one of the drawbacks in the manufacturing facility in which the inspector is provided with the normal medical insurance coverage which obligates each employee to go through a full medical checkup on a yearly basis.

The frequency of that medical checkup was found not enough to discover any eyestrain that could cause eye weakness in the right time or as early as possible.

In addition to that, the medical records for the inspectors were not found kept or monitored.

7. Workstation Design

The analysis of the current workstation design parameters is the corner stone of this paper as it will create the basis on which the new design parameters will be built. The current inspection workstation design is full of data and parameters that can be addressed, but for simplicity and to be focusing on giving realistic HFE solutions, the parameters that are covered can be shown in the following list:

- The chair (height + mechanism)
- The lighting.
- Inspection conveyor

The Chair

The chair used for the seating of the inspector in the workstation was found made of steel frame with height of 70 cm from the working ground and with a gap between the conveyor belts, where the tile is moving, and the chair seating edge is 30 cm. The chair is rigid and fixed to the ground which is not allowing the chair to move or respond to inspector movements. The chair is allowing most of the inspector to have a focus distance of 28 cm.

The current chair design is not allowing the inspector to take a good position which enables better focusing distance on the ceramic tile. In addition, the current chair design is not responding to any movements done by the inspector as a response to tile movement on the conveyor which in turn force the inspector to tilt his back and neck several times to follow the tile movement.

The lighting

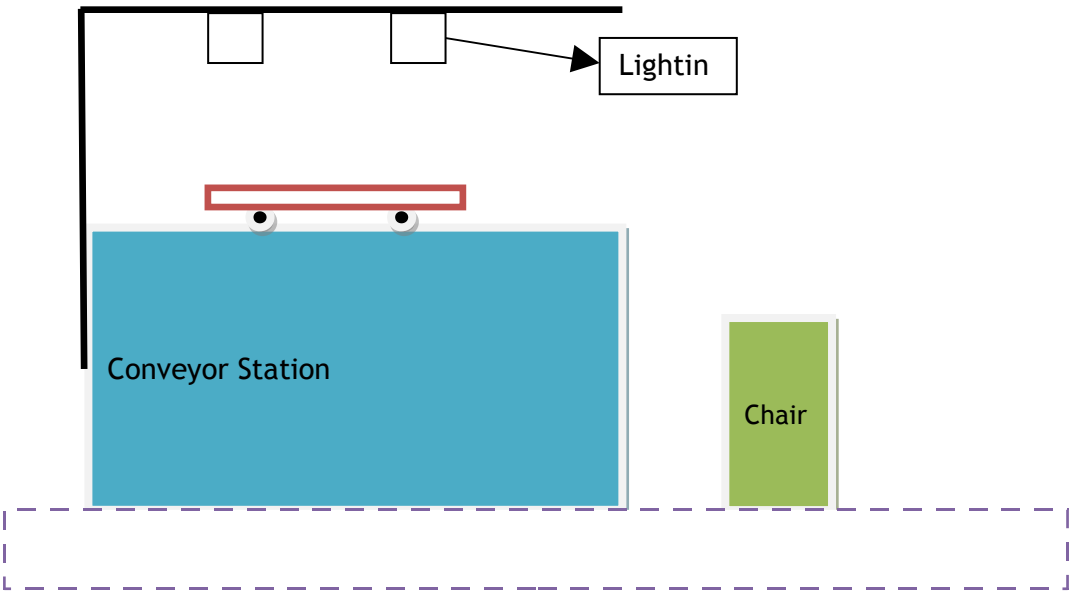
The current workstation design is providing a lighting fixture located on top of the conveyor by 100 cm. The lighting fixture consists of two lamps that provide 2500 luminous flux each.

By looking deeper in the lighting fixture, it was found that the provided lighting is avoiding any glare because it is placed outside the cone of 60 degrees around the line-of-sight. The illumination provided is considered of high intensity which is enough for that type of inspection.

The inspection conveyor

The inspection conveyor provided moves with a speed 0.12 m/s in a distance of 120 cm. The tile moves on the conveyor with the same speed while being inspected. The inspector has to follow the moving tile from the start point to the end point of inspection and then return back to the start point for the new tile. That repetitive neck motion is done almost 120 times in one hour.

That highly repetitive motion could be one of the causes of neck tension syndrome. In addition, the eye is trying to fix the tile picture while the tile is moving to enable the eye to search for surface defects and this causes the focus distance to change while the tile is moving which could result in visual fatigue.



The analysis done for the main problem took place in different stages till it reached final conclusion about the HFE shortcomings in the inspection process that should be tackled with proper corrective actions and countermeasures. Those HFE shortcomings are summarized as follows:

- The chair is fixed and rigid:
    - Focus distance cannot be changed
    - Cannot be tilted to allow the inspector to follow the moving tile while inspecting it.
- The tile is moving with a speed 0.12 m/s
    - Neck is moving in repetitive motions from left to right more than 120 times each hour.
    - Focus distance changes while the tile is moving.
- The frequency of medical checkup is not sufficient to detect any potential eye weakness.
- The working hour arrangement forces the inspector to work for 90 minutes and get a break of 30 minutes only.
- Training final assessment
- Training procedures.

In the next section from this paper, the above mentioned points will be tackled with HFE countermeasures, in order to eliminate their effect on the inspector and the inspection process.

HFE Countermeasures

The HFE countermeasures are mainly the aimprovement actions that should eliminate the identified root causes and will ensure that after re-measuring the inspection process, the desired targets could be achieved.

After studying all the possibilities, it was found that the HFE countermeasures should take one of two approaches:

1. To keep the tile moving while inspection
2. To stop the tile for inspection

The first approach will not change the way the ceramic tile is handled for inspection but it focuses on how the inspector is moving during the inspection process and how he responds to the moving tile and focuses on providing him the flexibility in movement.

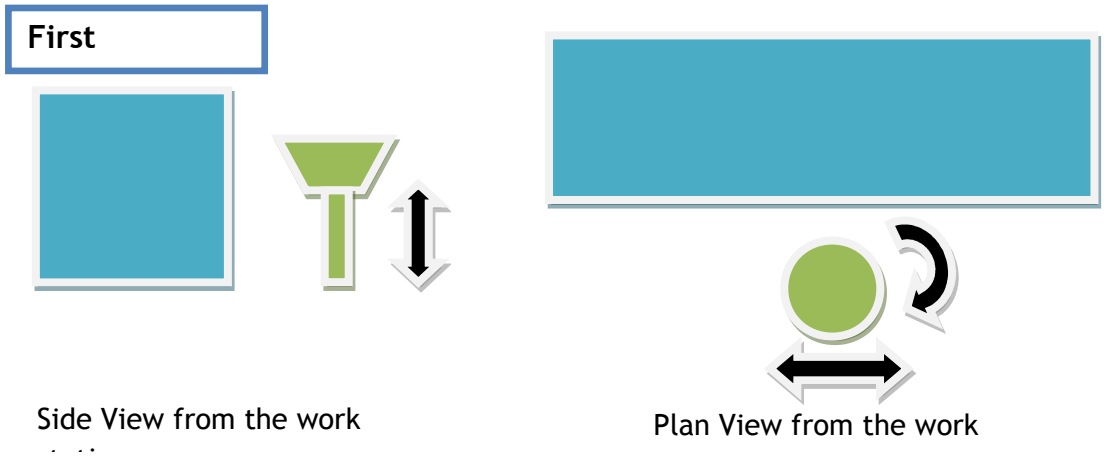
The second approach will change and modify the mechanism of handling the tile to the inspector to enable the tile to stop for a certain time for inspection and then move to the sorting machine.

The following table is showing the HFE countermeasures for the first and second approaches separately:

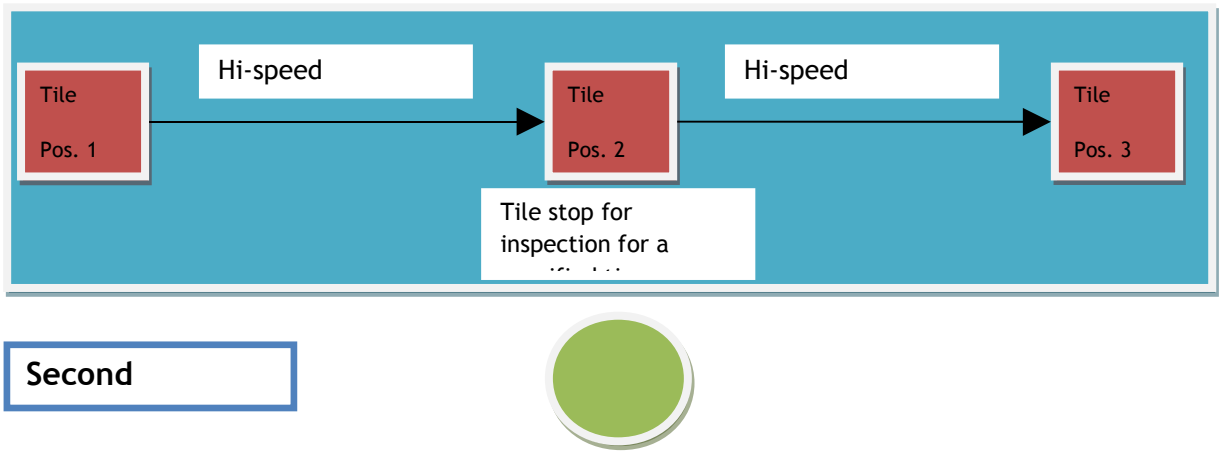
	HFE Countermeasures	
	Fist Approach	**Second Approach**
1	Provide the inspector with a chair that has a special mechanism which allows the inspector to tilt in circular motion, adjust its height and adjust its distance from the conveyor which will allow the inspector to adjust the focus distance as per his convenience.	Modify the mechanism of handling the tile to enable the tile to move very quick movement from the start point to the inspector's position and then stop for inspection for a specified time and then move quickly to the sorting machine. In addition to an adjustable chair.
2	Frequency of medical checkup to be increased to one checkup every 2 months.	Frequency of medical checkup to be increased to one checkup every 2 months.
3	The working hours to be changed to 60 minutes of continuous inspection work and then 60 minutes in any other light duty job.	The working hours to be changed to 60 minutes of continuous inspection work and then 60 minutes in any other light duty job.
4	The training program to be	The training program to be

	modified to include more difficult assessments with a designed arrangement of ceramic tiles having different type of surface defects.	modified to include more difficult assessments with a designed arrangement of ceramic tiles having different type of surface defects.
5	Modify the training procedure to allow the inspector to be trained on different production lines and in different shifts	Modify the training procedure to allow the inspector to be trained on different production lines and in different shifts

All the HFE countermeasures are similar except number 1 as shown in the previous table. And to give a clear picture for both countermeasures in the first and the second approach, the following drawing will simplify the modification needed in both approaches.



The above figure is showing the chair position and the modifications needed represented in the arrows that indicate the required degree of freedom.



The above figure is showing the change required in the mechanism of handling the tiles.

Re-measure

After applying the HFE countermeasures, it is required to measure the inspection process again to evaluate the effectiveness of the countermeasures taken and to evaluate the need for further actions.

The expected results should be positive by using both approaches. However, I believe that the second approach is much better as it eliminates the repetitive movement of the neck which could cause neck tension syndrome.

Conclusion

As a conclusion, the workstation design parameters have been changed as shown in the HFE countermeasures table, in addition to work procedure and training procedures. But the main change is the change that should be provided to the chair and the change that could be provided in the mechanism of handling the ceramic tiles at the inspection workstation.

The decision to apply the new design parameters should be based on how the results are effective in achieving the desired goals.

References

Karl, H.E K, Henrike, B. K., Katrin, E. K. (2003). *Ergonomics: How to design for ease and efficiency.* New Jersey, Prentice Hall.