THE EFFECT OF DOWNSTREAM QUALITY INSPECTIONS ON OVERALL SYSTEM PERFORMANCE: A CASE STUDY AT A FORGING COMPANY

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ABSTRACT

A strategic Original Equipment Manufacturer in the automotive sector delivers forged suspension components to the South African and International markets. Issues related to quality were identified, and to address these, the old batched quality inspection process was improved by creating an in-line quality testing station. The objectives of the inline quality inspection were to eliminate batching of items, including unnecessary movement of items, to increase the productivity of inspectors and to clear factory floor space taken up by the inventory and process space for batched inspection, eliminate the inherent risk of delayed identification of systematic production defects, reduce opportunities for re-handling, introduce a standardised inspection methodology, and ensure equitable inspector utilisation.

These objectives were met. The innovation also reduced quality errors, coming from upstream processes, which was unexpected.

This paper will explore how this quality improvement was achieved considering that the inspection stage itself had no operational function. Thanks to unexpected gains in quality, the break-even point for this innovation was remarkably short.
1 INTRODUCTION

Foxtec-Ikhwezi is a local manufacturer of original equipment (OEM) from non-ferrous metals. The company is located in the Eastern Cape city of East London (Industrial Development Zone, IDZ 1F) and is a joint venture entered into by Otto Fuchs AG and Ikhwezi Investment Holdings.

Foxtec-Ikhwezi produces forged aluminium suspension components for use in locally manufactured vehicles as well as for the export market. Due to several reasons, the process is a hybrid process of batched manufacturing and single piece flow. The quality inspection is currently a batched off-line process and features significant waste due to re-handling, transportation, and work duplication. It has been proposed that the quality inspection should be transformed into an in-line function, with less handling and transportation.

This study required the evaluation of repositioning the quality inspection from a batched into an in-line process by the use of innovative inspection workstations, and showing the advantages of such a move.

1.1 The product

Foxtec predominantly manufactures products vehicle suspension struts as shown in Figure 1. Foxtec exports between 85-90% of their product and the remainder is used locally. The material used is an alloy of aluminium which presents a significant weight to strength ratio for this product’s particular application. The typical material properties can be summarised as being “artificially ageable with medium mechanical strength, weldability, and good corrosion resistance.” (1) This product is a safety critical feature of a vehicle and thus its functional quality is a strict requirement.

![Figure 1: The different product types](image)

Despite the different product types the manufacturing process is generally the same for all of them, the fundamental variant being the forging dies used in the forge press for each product. The dies determine the geometry and dimensions of the product.
1.2 The process

![Process flow at Foxtec](Image)

Step one: Pellets with aluminium rods (raw material) forklifted out of the transportation truck and placed in the furnaces receiving bay.

Step two: A series of furnaces and quench tanks prepare the raw parts for forging and heat-treatment as required.

Step three: The main forge has a capacity of 2 100 parts in 24 hours. This forge allows for multiple dies to be used based on the required product.

Step four: The parts buffer section hold a significant number of uninspected parts.

Step five: The inspection hall has 6 inspectors sitting in pairs in on three inspection tables. They inspect each and every forged part coming from the parts buffer.

Step six: The Kanban area stores the inspected parts in predetermined rows as directed by the pull from the Just in time orders and the scheduled parts to be produced.

Step seven: The parts are machined by CNC machines which also insert rubber bushes.

Step eight: The just in time collection bay has the parts packaged in readiness for collection by the just in time truck from the Mercedes Benz plant down the road from Foxtec.

Step nine: Parts that are destined for export to international markets are packaged and stored in the warehouse for export.

1.3 Current State summary

The inspection department consist of three work stations that have two inspectors per station. The inspectors carry out quality checks on all products leaving the forging department by performing a 360° visual inspection on the parts.

The inspection department is located after the forge and it is configured as a section on its own. The rate at which the inspection is done per part is undetermined yet accumulation of work shows that it is slower than the output of the forge. A knock-on effect is that parts required by the CNC section risk not being at the Kanban section as and when required. To overcome this, extra inventory is held to offset CNC demand.
The scenario described above alludes to a three pronged problem where Foxtec has to; firstly contend with the risk of unknown quality of thousands of products in buffer between the forge and the inspection station, secondly bear the cost of the waste inextricable to overproduction, and thirdly waste further resources trying to manage the excessive inventories before and after the inspection section.

Moving the inspection section in line with the forge such that they function in tandem rate will ensure that there is no build-up of inventory or backlog and possibly reduces the excessive size (from an inventory perspective) of the Kanban area.

2 LITERATURE REVIEW

2.1 Forging defects

Forging is a plastic forming process in which heated or cool metals are exposed to very high pressures which allow the material to assume the shape of negative tooling. Having an understanding of this process is critical in this study as this is the primary process of manufacturing at Foxtec.

Forging as a metal forming process produces metal products requiring little or no finishing when compared to casting and machining. Defects do occur during the forging process but it should be appreciated that fundamentally these defects are not inherent to the process itself. To elaborate, if a forging concern experiences a particular type of defect the cause of the defects should be identified and fixed, this will prevent recurrence of the defect, as long as the process parameters are properly configured the process will yield good quality products. (12)

Poor process and preform design are the main causes of most geometrical defects on forged parts. The following geometrical defects can occur during forging: laps, folds, under-fills, eccentricity and piping. Folds are the most common geometrical defect. The inspectors identify such defects.

2.2 Work study

“The term work study is defined in the British Standards as ‘A management service based on those techniques, particularly Method study and Work measurement, which are used in the examination of human work in all its contexts, and which lead to the systematic investigation of all the resources and factors which affect the efficiency and economy of the situation being reviewed in order to effect improvement’ (4).”

The fundamental objectives of work study can thus be thought of in the following way;

• Determining the most effective use of plant equipment
• Determining the effective use of human effort while working
• The evaluation of human work. (4)

In this study, the primary focus of work studies would be determining the effective use of the inspector’s effort while executing their duties and evaluating the activities involved in the inspection process. This is hoped to be accomplished specifically through time and method studies, two major constituents of work study.

2.3 Root cause analysis

This is a tool designed to assist in the identification of what, how, and why a problem occurred. Only when analysts are able to determine what, how, and why a problem occurred will they be able to specify workable remedial measures that prevent re-occurrence of the
problem in question. (5) This may seem elementary but in complex processes, identification of the exact problem may not be clear. For instance, many processes have a lot of “fat” built in to them, evidenced by say over production; problems that do surface are masked in terms of their root cause since the process is still able to continue operating from the buffer built up by over production. An exact definition of root causes is difficult to establish from general literature but the following points are a succinct attempt:

Root causes are:

- specific underlying causes
- causes that can be reasonably identified
- those management has control to fix

those for which effective recommendations for preventing re-occurrences can be generated (5)

These literature definitions provide guiding principles that will be utilised in this study when identifying the root causes of identified challenges.

2.4 In-line design

Moving to one piece flow presents significant advantages, including:

- Reduced lead times
- Dramatic changes in transport
- Improved space utilisation
- Early detection of production problems

In this study it is anticipated that the moving of the inspection process into an in-line process will confer the above advantages

2.5 Automation

By replacing manual work with an automated process, error rates can be reduced significantly. Despite automation being viewed as an avenue by which to minimise human error in a system, increasing the degree and complexity of the automated process exasperates the consequence of an error becoming catastrophic, “This high degree of process automation requires a high degree of monitoring and control of process and product quality.” (6)

To contextualise the above paragraph, the process at Foxtec is such that the forging process is extensively automated and from the time the raw metal bar stock is loaded onto the furnace to when it leaves the tail end shot blast machine it is only handled once (a process which in itself is being considered for automation). Despite the automation, defects do occur for a myriad of reasons thus necessitating the inspection of each part at the end of this process. The disconnection at Foxtec comes in the form of a manual inspection process for parts that are made by an automated process. This disconnect could be the genesis of the problems currently being experienced in the inspection department. Granted, the inspection of each part requires many steps and the reworking of the parts (grinding) would be a challenge to automate but the manual process has to keep up with the automated process it is monitoring. The goal implicitly therefore, would be to get the inspection process as close as possible to automation and those aspects that prove to be challenging in terms of automation left manual.
3 DESIGN METHODOLOGY

The envisioned in-line design will comprise of three sub systems, which are standardised inspection procedures, workstation configurations and procedures and work table ergonomic design.

3.1 Standardised inspection procedure

The design of the standardised inspection procedure was done in consultation with the quality manager and the inspectors. It was structured such that it could be used for any type of product. It was also structured so that the inspectors have to fully inspect the part before performing any grinding procedures, this way they will avoid wasting time grinding parts that will eventually be scrapped or sent for re-work at shot blasting.

The quality manager advised that inspectors should run their eyes from right to left while inspecting a part because the process of analysing from right to left goes against the natural left to right process taught when reading or writing. By doing this the inspectors are likely to be more meticulous while inspecting.

Work study principles of time studies and method studies (work measurement and human movement) analysed in the literature review were instrumental in the standardisation of the inspection process.

3.2 Work station configuration

Three locations were identified as shown in the following schematic.

![Figure 3: Potential workstation locations](image)

The locations identified are shown by numbers 1, 2, and 3.

Location 3 was selected as it is close to the shot blast machine, though it presents significant floor space constraints. To avail more space next to the shot blast conveyor, the general manager says the extractor can be repositioned at the back of the shot blast
machine. This location is the most ideal with regards to ensuring the in-line design results in the advantages highlighted from the literature analysis.

A configuration was selected where all the inspectors are on the same work station with their own work tables. The following schematic shows a proposed design layout, it shows the top and side views respectively.

This design allows for one piece flow alluded to in-line design literature with the accruing advantages of: reduced lead times, dramatic changes in transport, improved space utilisation and early detection of production problems.

Figure 4: Proposed layout of new in line inspection system

3.3 Work table ergonomic design

The inspectors work table is a constituent component of the inspection workstation. This section looks at the ergonomic design of this component as a part of the workstation, based on the work study literature that elaborated on evaluation of human work.

The following is a schematic of the work table proposed design, it shows the front and top views respectively.
4 RESULTS ANALYSIS

4.1 Layout

The current floor space used by the inspection hall, inclusive of the bin storage area is 102m². The proposed new system will free up this space. The proposed inspection work station will at most cover 60m².

Currently every inspector travels an average of 1256 km per annum to retrieve and deliver material. The proposed system would eliminate this distance travelled entirely.
The physical location of the inspection bay next to the forge area will allow for better oversight from team leaders and management and allows for improved communication between the various functions within the plant.

The waste resulting from re-handling and batching will be eliminated.

4.2 Cycle time

The resulting cycle time for a part through the inspection system will be 8 seconds. This is because the non-value adding activities will be eliminated and the inspection time becomes the process time. Based on this the new cycle time is a 43% improvement from the current cycle time of 14.6 seconds.

4.3 People and process

From a people perspective the following benefits are accruing to the proposed design.

- Ergonomically:
  - The new work table eliminates the risk of injury
  - The work area is designed to allow the inspectors access to all areas of the table without over stretching and twisting
  - Adjustable grinders will ensure good posture regardless of the workers physique
  - Motion fatigue is reduced as all the chutes for the parts do not require any extra lifting by the worker
  - Quicker and easier access to the VIS (Visual Inspection Sheet) through the visual reminders on the partitions
  - Quicker and easier logging of defects
  - Improved flow reduces transportation distances by over 1200 km per year including associated productivity and wellness gains.

- Innovation with respect to the inspection methodology can be achieved from the set standardised method

- Equal work loading will be achieved

- Job enrichment will be enhanced by making the inspectors play a more active role in the structuring of their work in terms of scheduling and determining reward measures. This will be done primarily through the shift head inspectors.

From a process perspective, the elimination of non-value adding activities as alluded to throughout this section is critical. Another big benefit is the real time SPC charts tracking the different defect types that the inspectors are picking up. These charts on the work station computers will allow the immediate pick up of defects allowing for prompt process corrections from the forging department.

4.4 Cost benefit

The benefit that stands to be gained from the proposed inspection system is greater than financial savings but such an analysis is required to justify funding this implementation.
The floor space availed by implementing the new system is 102 m². This space will be utilised for other production activities within the factory. The cost of expanding the factory floor space at Foxtec is estimated at R 5,000 per m². This means that a potential saving of R 500,000 is realised just by making available the extra floor space.

Based purely on salaries, the annual opportunity cost due to poor utilisation is R 344,000 per annum. Additionally, the current inspectors structure takes inefficient practices into account, meaning that 25% of inspectors can now be redeployed elsewhere in the factory.

There is a potential cost saving associated with eliminating the risk of having inventories of parts yet to be inspected. This benefit should be appreciated but analysis of it was not done due to limited access to information on the number of parts re-worked and scrapped yearly.

5 SHORT FEEDBACK LOOPS

Prior to the introduction of the inline quality inspection station, the average rejection rate of components was 4.2%. This was reduced by over 50% to 1.6% on average. This is unexpected, as both quality inspections take place downstream from the forge, and should therefore not be able to affect the quality of products produced there. It is however a recorded fact that this did occur, and it is our contention that the immediacy of the in line quality inspection station allows inspectors to feed quality issues back to the forge immediately, meaning that an incorrect setup does not go unnoticed until the batch produced on a particular run is finally inspected. This short feedback loop is a driver of quality change upstream and paid for the significant cost of purchase, design and installation of the inspection station within a period of less than a year.

6 REFERENCES

foxtcikwhezi.co.za/index.php?/automotive_products. [Cited: 12 August 2011.]