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REVIEW OF TRACEABILITY SYSTEM APPLICATIONS. CASE STUDY: THE WIRING HARNESS INDUSTRY

REVISIÓN DE APLICACIONES DE SISTEMAS DE TRAZABILIDAD. CASO DE STUDIO: INDUSTRIA ARNESERA

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Resumen

El objetivo de esta investigación es el desarrollar una metodología de mejora para un proceso producción de arneses que permita obtener la trazabilidad de los productos que se procesan en un área específica, en este caso en un área de inyección de espuma, mediante la implementación de un sistema de monitoreo electrónico por medio de código de barras. Los pasos de la metodología presentada constan de un análisis previo del área, el desarrollo de un programa de trazabilidad, la implementación del sistema, y la evaluación de los resultados. Gracias a la información brindada por el nuevo sistema de trazabilidad se identificaron los principales defectos en el área, y se tomaron acciones específicas para minimizar la reincidencia de estos, mostrando una disminución del 23% de los defectos después de un mes de nuevas pruebas.

Palabras claves: Trazabilidad; Código de Barras; RFID; Industria arnesera.

Abstract

The purpose of this research is to develop a methodology for improving a wiring harness production process that allows for tracing the products that are processed in a specific area - in this case in a foam injection operation - by implementing a bar-coded electronic monitoring system. The steps involved in this methodology are as follows:

a prior analysis of the area; development of a traceability program; implementation of the system and, finally, evaluation of the results. Thanks to the information obtained through the new traceability system, the main defects in the area were identified and specific actions were taken to minimize their recurrence, achieving a 23% reduction of defects after one month of trials.

Keywords: Traceability; Barcode; RFID; Harness industry.

Introduction

Information and Communication Technologies (ICT) have advanced rapidly, increasing the opportunities for companies to integrate them into their supply chain. ICTs offer organizations the possibility of improving their competitiveness, as well as the capacity to respond immediately by adapting their operating strategies, methods and technologies to data almost in real time (Musa & Dabo, 2016).

It is very important for organizations to achieve an agile and efficient flow of information. For this purpose, product identification and data capture systems, such as barcoding and radio frequency technologies, are available to identify and track products throughout the supply chain. This capability offers multiple benefits for organizations, given the significant number of transactions executed daily, since information is required for the planning and control of all the operations of those parties involved in the supply chain, including suppliers, producers, carriers, distributors and customers. Therefore, production flow traceability represents added value and an effective way to fulfill norms and legal requirements (Correa et al., 2009).

The term 'traceability' is defined as the ability to track and locate products, batches or components throughout the supply chain from its first stage until they reach the end user (Hockenberger, 2014). López (2006) synthesizes the definition of traceability as the set of pre-established processes required to know the location and trajectory of a product throughout the supply chain, enable the precise identification of the raw materials needed to manufacture it and the processes through which it passes, as well as knowing the destinations to which it has been dispatched.

Traceability systems are commonly used to track a product within a process; however, many definitions are used depending on the sector to which they are applied. In the case of agriculture, for example, authors such as Sepúlveda et al. (2009) propose 6 types of traceability: product, process, inputs, conditions, genetics and measurements.

Increased operational efficiency, the ability to track the product more efficiently, a faster response capacity and reduced labour costs are just some of the advantages of traceability systems. They also allow organizations to pinpoint specific problems in the manufacturing process, without having to involve a major part of the personnel (Rădulescu & Popescu, 2014).

One of the most widely used traceability technologies is the barcode, due to its rapid scanning speed, accuracy and high-speed capturing of information, when compared to manual data capture (Wasule & Metkar, 2017). This technology is employed in multiple industries and markets (Rădulescu & Popescu, 2014), since it can capture information automatically and unequivocally (Correa et al., 2010). Barcoding plays a vital role since it allows companies to automatically track products throughout the supply chain (GS1, 2018).

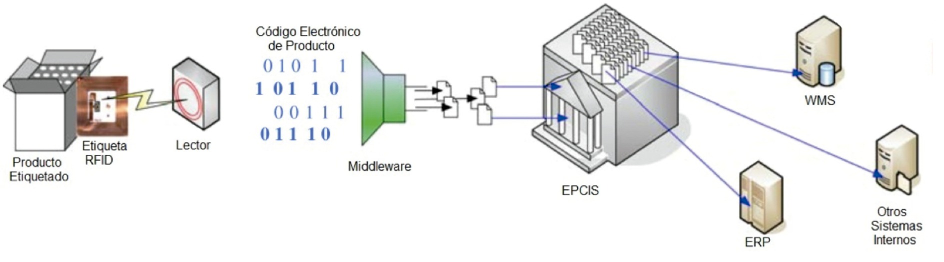
In Figure 1, Li et al. (2003) indicate the components of a barcode system - a scanner, the labels with the code, a computer system and a specific software.

Figure 1. Components of the barcode system (Li et al., 2003).

Radio-Frequency Identification technology, or RFID, is an automatic system of identification and acquisition of information that identifies and transfers production and business data by radiofrequency waves (Correa et al., 2010).

RFID consists of an electronic label that fulfills the function of a transmitter and a signal receiver supported by a decoder system (middleware); through the label, identification data are stored and transferred to the signal receiver by radiofrequency waves. The system processes the received data in order to identify and monitor the product as it passes through the manufacturing process, sending the data to a server which sends them to other internal information systems (Ramírez, 2013, Musa & Dabo, 2016, Hozak & Collier, 2008). In Figure 2 Chen et al. (2007) identify the elements of an RFID system.

Figure 2. Components of an RFID system (Chen et al., 2007)



QR (Quick Response) technology, on the other hand, is not precisely a traceability system because it does not store information, it only provides data to the user who scans the code. Nevertheless, in some companies it is used to help personnel track the product and facilitate the way to communicate information to a certain user. QR technology uses a two-dimensional barcode that is quickly identified using a mobile device equipped with a camera and a dedicated QR code-identification software. This technology has broad information communication capacity, a small print area, rapid scanning, advanced error correction and freedom to scan in any direction (Xiao et al., 2017). This type of coding is used in many different fields, ranging from marketing, social networks, education, health and product traceability, among others (Pal & Jha, 2017).

Application of traceability systems in different areas

In recent years there have been multiple studies of the different applications of traceability systems, in a wide variety of sectors, as summarized in Table 1.

Table 1. Application of traceability systems.

Field	Summary	Technology	Reference
Agriculture	A traceability system for agricultural products is proposed for consumer safety.	Public key infrastructure	Sepúlveda et al., 2009
Agriculture	An analysis of a model of a traceability system using Big Data and the Internet of things for agriculture and food safety is conducted.	Big Data	Giagnocavo et al., 2017
Automotive industry	The interface to migrate from barcode to RFID in automotive logistics is analyzed.	RFID	Schmidt et al., 2013
Food industry	An Act (FDA Food Safety Modernization Act) is proposed in the United States that requires that the producer implement food traceability for consumer safety.	Barcode	Rickard, 2011
Food industry	A system with a QR code is implemented to monitor the stages of marine products, ensuring that they are at adequate temperatures.	QR	Xiao et al., 2017
Health care industry	A barcode traceability system is implemented to help with medication, reduce errors and waiting time, as well as to provide greater patient safety.	Barcode	Casado et al., 2015; Miller et al., 2013; Seibert et al., 2014; Wild et al., 2011; Wang et al., 2016.

Field	Summary	Technology	Reference
Livestock	A national barcode system is implemented to know the stages of transformation of livestock from birth to the point of sale.	Barcode	Dassatti, 2015
Manufacturing	The simulation of a model is carried out to compare the efficiency of traceability systems in a manufacturing process.	RFID, Barcode	Hozak & Collier, 2008
Manufacturing	An RFID System is implemented in a blind manufacturing company.	RFID	Ramírez, 2013
Pharmaceutical industry	A summary of the importance of drug traceability is made, from production lot to the point of sale.	RFID	Hockenberger, 2014
Pharmaceutical industry	A barcode system is implemented in a hospital pharmacy for the correct supply of medicines.	Barcode	Louden et al., 2017
Warehouses	A barcode system is implemented to improve the service in a university library	Barcode	Rădulescu & Popescu, 2014; Vasishta & Dhanda, 2010
Warehouses	A barcode system is implemented to reduce costs and loss of letters and packages in a school post office.	Barcode	Asher-Schapiro, 2014
Warehouses	A pallet traceability system is implemented inside a warehouse	RFID	Ángeles, 2005
Warehouses	A barcode system is implemented in a warehouse for pallet traceability.	Barcode	Bond, 2015

Field	Summary	Technology	Reference
Warehouses	An RFID system is implemented to optimize the management of a warehouse in the steel industry	RFID	Xu et al., 2013
Warehouses	The management and redesign of a warehouse is improved using VSM and an RFID system	RFID	Chen et al., 2013
Warehouses	An RFID system is implemented to simplify selection processes and increase productivity in a warehouse.	RFID	Pane et al., 2018
Warehouses	An RFID system is implemented to improve the management of inventory and operations in a warehouse.	RFID	Wang et al., 2010

New trends in traceability systems.

There are many applications for QR codes; however, their potential is impressive, either in sectors where their use has not been widely explored or where they have simply not been promoted enough. QR codes have applications that range from Wi-Fi access, payment codes, online stores, access to websites (Sammons, 2018) and even as a tool to provide extra information on a person or product in summaries or business cards (Pal & Jha, 2017).

QR code usage boomed in 2015, thanks to "Snapchat", a social media application where "Snapcodes" helped users connect much faster than usual by simply scanning the set of points that functioned with the user's ID. The WhatsApp web application currently uses the QR code to recognize an account when opening it on the computer (Sammons, 2018).

These codes can be printed anywhere, so a person can obtain information from them but there is no feedback, and the information of the person doing the scanning cannot be obtained, so no history is generated which is crucial in multiple sectors (Sammons, 2018).

Technology is advancing rapidly, so there would appear to be no great future for QR codes. NFC (Near Field Communication) tags are a recent tool with the potential to replace QR codes. Among their major advantages are the fact that they don't need an extra application to be scanned, they are safer, more flexible, and easier to configure. In fact, most smartphones already have NFC chip technology, so when enabling an option, the user only must touch the device to perform an action through the NFC tag. Applications such as Google Wallet and Apple Pay use this technology (Emily, 2017).

While some point to the end of the era of QR codes, others seek their application in different sectors within marketing, such as coupons, and their usage is expected to exceed USD 5.3 billion in 2022, far exceeding the USD 1.3 billion obtained in 2017 (Iglesias, 2018).

Another variant of the QR codes, are the "ddTags" which are codes designed to help blind people, because they are activated without the need to bring the phone closer to the code, without headphones and at up to 150 meters (Justo, 2018). This project was born in Spain and has so far been tested in several metro and bus stations in Barcelona, but is expected to be standardized throughout Spain (Iglesias, 2018).

Case study

A case study is presented, which focuses on a foam injection process in a wiring harness manufacturing company located in northwestern México, a supplier for the automotive sector. The organization has customers around the world, especially manufacturers of heavy machinery.

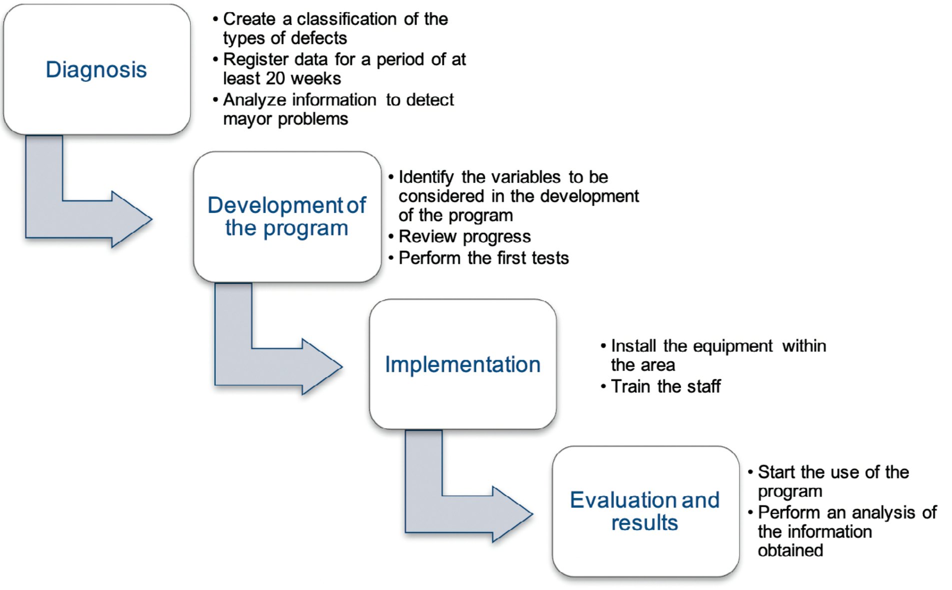
Due to the functions that the wiring harness has to accomplish inside the vehicle, it must have a special foam coating for thermal insulation. The process consists of preparing the mold by spraying wax on it so that the piece detaches easily at the end of the cycle. The harness is placed in the mold and foam is injected over it; the foam solidifies, the piece is removed and finally the burr of foam is cleaned. A large amount of material is discarded in the area, which translates into significant monetary losses. During the first quarter of the year, an average 77% of the economical amount estimated for defects was spent daily. However, this percentage is expected to increase, which is why the engineering area has projected that the established limit will be exceeded in the coming months.

There are multiple problems in the area, among them the underutilization of labor and machinery, lack of capacity to process the pieces and general lack of organization. It is worth mentioning that even though there is an ongoing control of the harnesses processed, of the number of defects and the efficiency per se of the process, there are many parameters that are not known on time, and in other cases the data do not match the reality of the process. Furthermore, information as to when and in what workstation each defect occurred, and the person responsible for it, is all unknown.

The option of a barcode system was chosen over RFID systems or QR codes, mainly because the company currently uses barcodes for product traceability in other areas, in addition to the low cost of implementing this technology and the ease with which the user is provided with information for managing the processes. Although each item already has a barcode label, these codes are not used in the foam injection process, but in this study they are used to provide internal process traceability.

Therefore, a barcode system was implemented to provide adequate control of the production in real time, informing the inputs and outputs of the products, as well as the efficiency and the percentage of defects per operator, mold, and workstation, among other benefits. With the information provided by the barcode system, future decisions will be taken objectively to improve the process. In short, the use of the traceability system will result in a reduction of defects in the medium term and an increase in the overall efficiency of the area. A four-stage work sequence was established, as shown in Figure 3.

Figure 3. Work Sequence



Stage 1: Diagnosis

In this stage an initial analysis of the area must be carried out; the files detailing the defects reported in the area will be examined in order to understand their main causes.

a) The historical archives of the defects detected in the area will be consulted and later grouped to have a maximum of 10 defects, and a code will be generated for each one. This new classification will be used in the traceability system.

b) In order to know which are the lines of the customers that report the greater number of defects, the discarded pieces must be analyzed, divided by line, or by client. Information will be collected according to the proposed new defect classification for a period of at least 20 weeks.

c) An analysis will be carried out to know the main defects that occur in the process and the main affected customers will be identified, these being the ones that generate the highest scrap and rework costs. Subsequently, histograms will be drawn up to graphically illustrate the results obtained.

Stage 2: Development of the program

In this stage an application will be developed for the traceability of the pieces processed in the area, adapted to the company's needs. It will be important to consider the spaces, the facilities, the workers and the time, for the efficient preparation of the software.

a) A list of the variables to be considered when creating the software will be compiled, with a careful description of each of them, which will be delivered to the team in charge of developing the program.

b) Regular meetings will be held between the systems department and the team of the work area to evaluate the progress in the development of the program and indicate any necessary modifications.
c) The first tests of the program will be carried out, simulating the normal operations of the process, scanning a worker's credential, the code of a mold and the code of a harness. In this way the advances in the program will be visualized and it will be possible to detect errors, before implementing it in the area. Subsequently, new dates will be agreed for new modifications, if necessary.

Stage 3: Implementation of the system

This stage will involve the installation of the equipment and software and training of the personnel of the area.

a) Once the tests have been completed, the system will be implemented within the area. It will be necessary to prepare the area with the required facilities, considering electricity, internet, and space requirements, as well as special cabinets to protect the computer equipment from the environmental conditions where it is located.
b) All the personnel of the area will be summoned: workers, engineers, and maintenance personnel and they will be informed about the software, its purpose and functionality, and a simulation will be carried out to understand the way the system operates so that all the personnel are capable of operating it.

Stage 4: System evaluation and results

In this stage the system will be tested in the area, and the results of the system's performance will be evaluated.

a)The process will be operated normally and will begin with the use of the program.
b)An analysis will be made with the information obtained, which will be documented and may be used later to take corrective actions within the process.

Short-term results

Stage 1: Diagnosis

The database with the records of the defects identified in the pieces above was used and grouped into 10 codes.

A classification of 10 defects was created. Table 2 shows the possible causes of the most common defects, as well as the possible solutions for each one of them.

Table 2. Causes and solutions for the main defects.

Defect	Possible causes	Possible solutions
Crushed cable	Neglect Poor handling of material Rush	Training Penalization

Defect	Possible causes	Possible solutions
Incomplete foam	Bad mix Poorly fitting of the piece in the mold Poor injection of foam	Check the mix regularly Clean the machinery Training
Wrong dimension	Piece manufactured out of specification Poorly fitting of the piece in the mold	Inspection when receiving material Training
Excess of foam	Bad mix Wrongly closed mold Piece too big	Inspection when receiving material Training Penalization
Missing / damaged component	Poor handling of material Badly placed component	Material handling training Continuous supervision Penalization
Damaged cable Training Penalization	Poor handling of material	Use the right tool

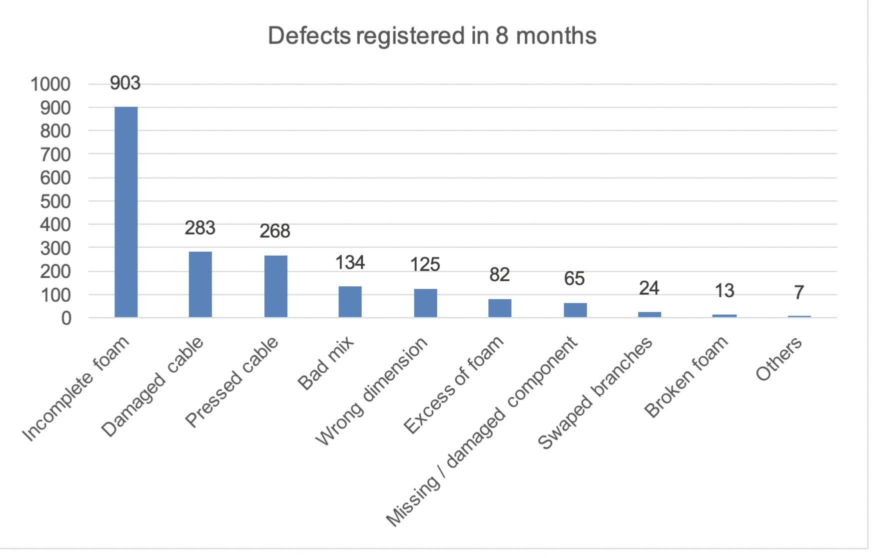
As can be seen in Table 2 not all the defects that may occur are the responsibility of the foam area, so Table 3 details the defects that may be attributable to other areas.

Table 3. Defects attributable to other areas

Defect	Responsible area	Reason why it is attributed to another area
Incomplete foam	Final assembly	The part lacks a branch cable.
Wrong dimension	a) Cutting area b) Final assembly	a) The cable does not have the correct dimensions due to a bad cut. b) The branches have incorrect dimensions.
Excess of foam	Final assembly	The piece is too thin and does not fill the mold cavities therefore the foam will be harder. If the piece is too thick, the foam will expand.
Missing / damaged component	a) Preparation area b) Final assembly	a) Cable with incorrectly placed terminals. b) Incorrect handling of the piece before taking it to the area; ineffective insertions of components, or missing components.

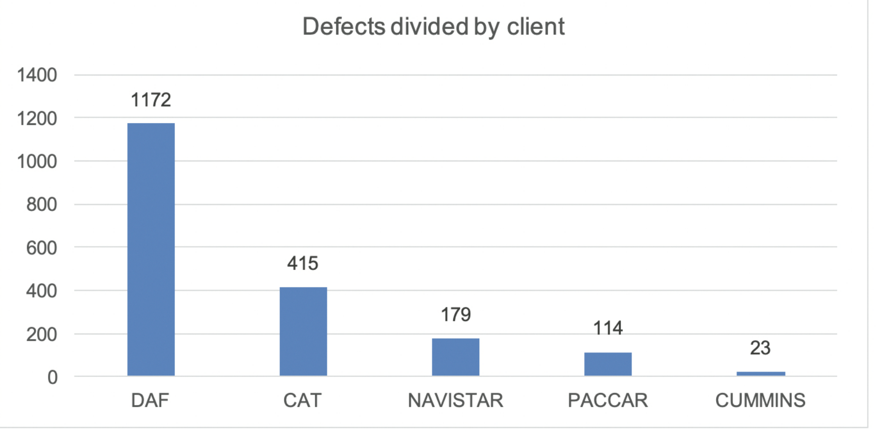
A record of defects was kept over a period of 8 months and it was found that the most frequent defect was "incomplete foam" followed by the damaged cable and crushed cable, as shown in Figure 4.

Figure 4. Defects divided according to the new classification.



It was detected that the customer in whose line there are most defects is DAF, where this head the costs of reworking, as shown in Figure 5, followed by CAT, which has less than half the DAF defects.

Figure 5. Number of defects, divided by client.



Stage 2: Development of the program

A list of the necessary variables was made for the software development and was given to the team in charge of its preparation. Dates were established for reviews of the progress of the program and this was enriched with the observations made at the meetings in which pilot tests were conducted by simulating the scanning of the product.

Stage 3: Implementation of the system

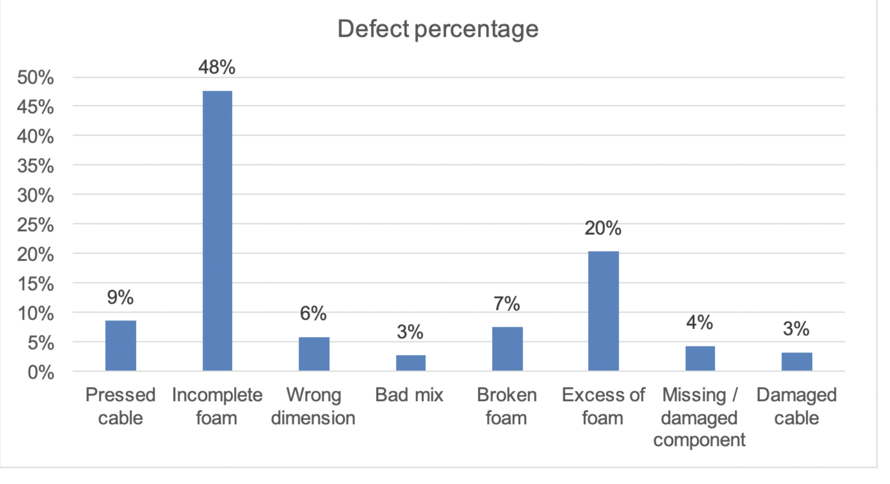
The area was prepared with the necessary facilities for the equipment and special cabinets were purchased to isolate the computing equipment from the environmental conditions of the area which was duly installed.

A meeting was called for all the personnel - workers, engineers, technicians, and maintenance personnel. A simulation of the functions of the program was performed and the general aspects of the program were explained, such as the downloading of the reports and their purpose, care of the equipment and the sequence in which the pieces are scanned.

Stage 4: System evaluation and results

In the first test period 187 cases of reworking occurred. 'Incomplete foam' was the most common defect, representing 48% of the total defects, as shown in Figure 6, followed by 'excess foam', which represented 20% of the total.

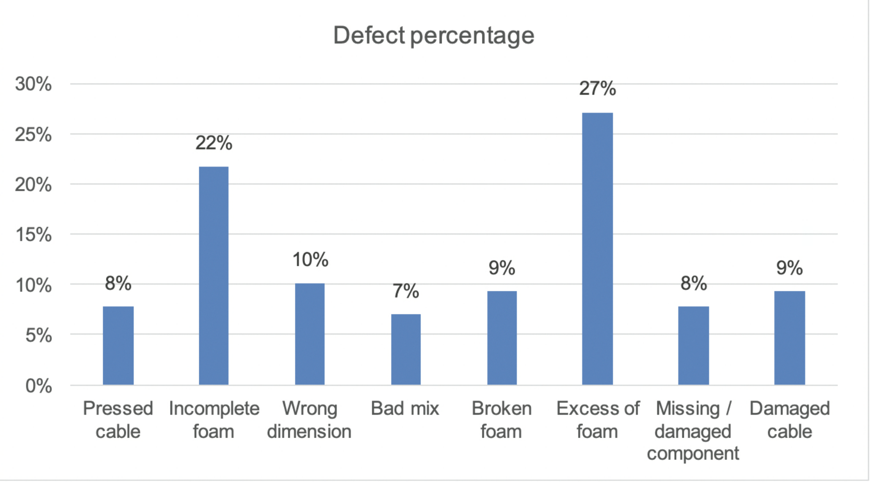
Figure 6. Reworks in the first test period.



Given the results, incomplete foam is the defect that occurs most, representing almost half of the defects of the area, therefore measures were focused on this defect, considering the main causes set forth in Table 2.

It was found that deficient training was the root cause of this defect so further training was given. Furthermore, 60% of the 'incomplete foam' defects occurred during shift No. 2, so worker discipline was monitored. After one month, new tests were taken and the percentage of 'incomplete foam' defects decreased from 48% to only 22%, as shown in Figure 7.

Figure 7. Defect percentage after taking measures.



In order to compare the improvement found after taking corrective measures in the process, thanks to the support of the new traceability system, the DPMOs (Defects Per Million Opportunities) are shown below, which are calculated as indicated in equation 1.

$$DPMO = \frac{(1{,}000{,}000\ x\ Number\ of\ defects)}{Number\ of\ units\ x\ Number\ of\ opportunities}$$

Given the total number of pieces produced and defects found in the first months of data collection, the DPMO of the company stood at 5,279. After working with the traceability system, the main defect was identified, namely incomplete foam, so after taking specific measures to solve this particular defect, the DPMO was reduced to 4,040. This represents 4% of total production, so if the process continues with the same variables as it shows now, there will be a total of 4,040 defects for every million products. Moreover, dividing the DPMO results before and after the implementation of the system, defects are seen to have been reduced by 23%, thanks to the precise detection of the factors that caused the defects and the corrective actions taken to remedy them.

Conclusions

Companies are continuously searching to improve their processes and for this it is essential to have the right tools on hand for intelligent decision-making. Sometimes people are looking for major solutions that require significant investments of time and money for what are in fact minor problems. In most cases, however, problems can be solved using tools that are already available within the company. This shows the importance of thoroughly understanding all the organization's processes, because this will facilitate the determination of solutions to the different problems.

In this case study, the traceability systems proved to be a fundamental part of the process, since the barcode technology was already being used in the company, but not in the foam injection area. The fact that a very similar system was currently being used in the company, made it easy to extend it to the studied area.

The most common defect was incomplete foam; nevertheless, there were several causes for this, and with the support of the traceability system it was possible to identify the workers with most responsibility for this problem. Moreover, it was found that the second work shift accounted for more defects than the first one. Thanks to the barcode system, specific actions were taken that sought to directly attack the root causes of the problem. The recommendation is to continue searching, with support from the traceability system, for the most common defects and to identify their main causes. This system can also be implemented in other areas of the company, in order to improve the overall efficiency of the processes.

Conflict of interest

The authors of this manuscript state that there are no conflicts of interest with any entity or institution, or of a personal nature in this publication.

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