USE OF POKA YOKE AND DESIGN FOR MANUFACTURING AND ASSEMBLY ON NEW PRODUCTS´ DEVELOPMENT

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Abstract. *As competitiveness and market requirements are more stringent, new products must be designed to be simple from the manufacturing point of view and low cost, among many requisites. Two techniques to improve these requirements are* ***Poka-Yoke****, and* ***Design for Manufacturing and Assembly (DFMA****). As these methods focus on different aspects of a product, a design conflict might arise. For instance, a poka-yoke component might be eliminated from the product structure through the DFA analysis. Nevertheless these methods can be used together to improve project quality to the final costumer. This article aims to present and evaluate the two methods and analyze how they can be used simultaneously in a new product development. Some case studies are presented to elucidate the approach adopted.*

Keywords*: Poka-Yoke, Design for Manufacturing and Assembly, Product Development*

1. INTRODUCTION

In recent decades, engineering teams have been pressed to improve both quality and manufacturing feasibility of products. Globalization process, safety specifications, more stringent consumer requirements and market competition are making companies to design and produce better and cheaper products. Along the last decades, different methods were tested and implemented to achieve the objective of comply with user´s expectation, meanwhile improve industries´ profits. In manufacturing industries, Poka-Yoke and Design for Manufacturing and Assembly (DFMA) systems can be stated as important and widespread for this purpose.

Poka-Yoke devices and procedures are based on reacting against failures occurred, improving the system to not have reoccurrence. On the other hand, Design for Manufacturing and Assembly is applied during the product design phase, generating a product easier to be produced, consequently, cheaper. On a first sight, these approaches are aimed for usage by Manufacturing and Design teams, independently. It looks like they would not be used together. However, they are not concurrent, though complementary. This article presents the two methods and the benefits of using them in parallel along design phase to improve the quality of product.

The mindset of Designers and Manufacturers are different, and the success of the combination of these methods depends on management team to lead the development phase as a single target to achieve costumer satisfaction. As these methods are being known and become popular as quality and cost reduction improvements, engineers are being used to implement them in day-by-day activities.

Sections 2 and 3, briefly review, respectively, the Poka-Yoke and Design for Manufacturing and Assembly methods along with applications. Section 4 presents and analyses the interactions between these methods. It is important for engineers intended to apply both methods to understand their principles and where and how to use them. Synergies of methods can improve design process and final product quality.

2. POKA-YOKE

Poka-yoke, also known as error-proofing devices, is a failure avoidance system, acting as a simple manner to avoid reoccurrence and it is an important procedure within Zero Quality Control concept. The first known poka-yoke was introduced in a sewing press to detect fiber rupture and spinning wheel completion, so a single worker could operate more than one machine (Correia *et al* 2001). Shigeo Shingo (Shingo, 1986) who has worked with different kind of industries in Japan, used the principle, improved the method and applied it systematically on production lines. As the method was understood and correctly applied by the worker force the rate of defective parts was significantly reduced. A poka-yoke must be simple, cheap and easy to apply (Canossa, 2007). The correct and serious implementation of poka-yoke devices is so effective that companies report stations producing over a month without any defective part (Shingo, 1986).

The method was first applied as a reaction system, implemented after occurrence of the failure. The objective was to avoid reoccurrence of the failure and not let a defective part to proceed downstream on production, incurring in rework or scrap of product. Manufacturing teams focused on problem solutions, and workers were stimulated themselves to propose forms to avoid the failure reoccurrence. Initially the method was based on facilities adaptation to products. With its dissemination, products become to be also modified to incorporate error-proofing devices. As per Kosaka (2006) poka-yoke devices can be fully effective when:

- A manual process requires operator´s attention.
- Wrong positioning may occur.
- Adjustment is required.
- Attributes and not measures are important.
- Special causes may reoccur.
- Training and turn-over costs are high.
- Several products are assembled in the same production line.
- External failure cost is pretty higher than internal ones.

Use of poka-yoke can even mitigate need for specific training. Though training decreases error rate, when people leave the company knowledge is taken with, but assembly difficulties stay behind (Dvorak, 1998).

With the advent of concurrent engineering, when engineers stop to “throw designs over the walls” (Axtman and Murphy, 2007) design teams started to develop parts with poka-yoke capability, supported by manufacturing teams; so the failure could be avoid even before it first happened. Along with project and quality disciplines implementation, poka-yoke devices and procedures became, also, an output of Design and Process Failure Modes and Effects Analysis (DFMEA and PFMEA), when failure modes were identified.

Although the method might be applied for administrative and production processes, this paper is focused on the latter. Figure 1 presents examples of poka-yoke devices.

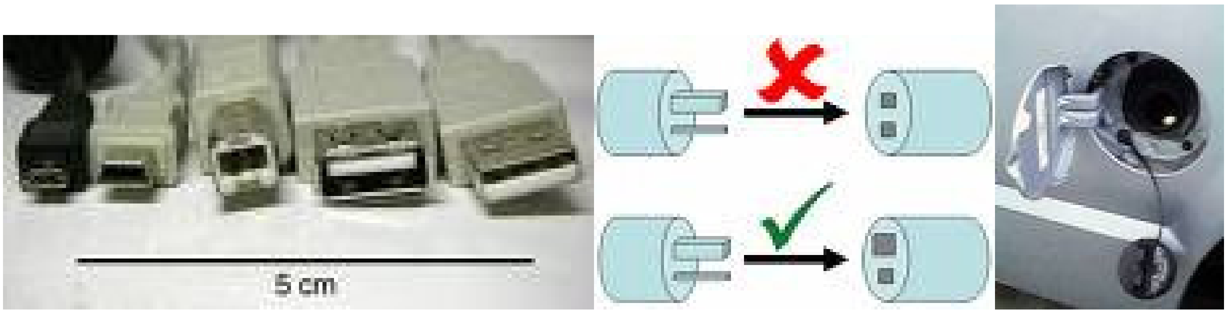

Figure 1. Poka-yokes used on computers (BizTalk, 2008), electricity (Free Logistics, 2009) and automotive industry (Acuario 27, 2007).

Among poka-yoke devices, the following might be cited:

- Sensors to identify an object and continue the process.
- Color identification.
- Stock similar tools on the same local.
- Machine is turned off when overloaded, avoiding system damage.
- A process only starts after the completion and verification of prior one.
- Machine is turned off when inspection door is opened.
- Part has only one possible position to be fixed to product.

Because poka-yoke devices are frequently introduced after production start, it may add features and cost to the product. As previously stated, cost reduction is an objective to all industries, independent of segment or size. So, poka-yokes shall be conceived in a manner not to add cost to it.

It must be kept in mind that errors cause defect, and defects are the effect of errors (Chao and Ishii, 2005).

3. DESIGN FOR MANUFACTURING AND ASSEMBLY

The method Design for Manufacturing and Assembly (DFMA) was developed by Geoffrey Boothroyd and Peter Dewhurst, (Boothroyd *et al*, 1994). The technique aims at developing products ease to be manufactured and assembled. The DFMA uses several concepts, tools and methods to simplify and improve the manufacturability and assemblability of products (Rozenfeld and Horta, 1999). Facing the challenges of market, and pushing production costs down, this approach can be used by all kind of industries, and has proved to be an excellent method to facilitate production. DFMA is important for either high or low volumes products (Boothroyd *et al,* 1994). Low volume products require it as well, usually because preliminary design analysis is usually not carried out, increasing dramatically handling and assembly time of components (Boothroyd *et al,* 1994). DFMA comprehends, also, an intangible benefit: simplifies engineering, planning and tooling (Gerding *et al*, 1998)

As shown in Figure 2, design phase is responsible for a large impact on product life costs, making extremely important the use of design tools on initial steps of the project. Although Concept Design is not an expensive phase, it influences around 70% of the total costs of the project (Boothroyd *et al*, 1994). It is in this phase that material, surface finishing and technical requirements are specified. Special attention and tools shall be employed to initiate a project on a right way. That is the reason why engineering teams must perform a full quality start of project, in order to avoid penalizing the product.

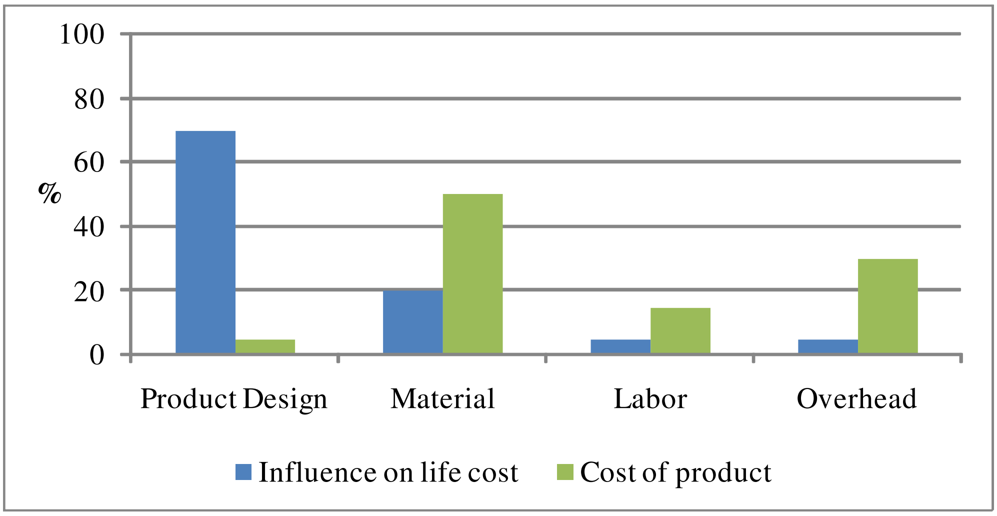

Figure 2. Impact of product cost (Boothroyd *et al,* 1994).

Some concepts of DFMA are (Rozenfeld and Horta 1999):

- Minimize numbers of components.
- Use of multifunctional components.
- Standardization of components and processes.
- Modular Project.
- Unidirectional assembly.
- Alignment and insertion of components.
- Elimination of screws, springs, wiring harnesses.
- Elimination of adjustments.
- Standardization of materials, finishes and components.

The reduction of the number of components follows a simple algorithm. The simplicity of the method is one of its benefits. No computational aid is required, and is based and supported by the knowledge of affected areas, including design, manufacturing, logistics etc. A simple questionnaire shall be filled to all components of the system to verify the necessity of a part, where three questions must be answered (Boothroyd *et al,* 1994):

- Has the component relative movement to neighbor parts (small motions that can be accommodated by integral elastic elements are not sufficient for positive answer)?
- Must the material of the component be the same of neighbor parts?
- Must the component be separate from neighbor parts to allow assembly and disassembly (small motions that can be accommodated by integral elastic elements are not sufficient for positive answer)?

If, at least one the answers, is YES, the component must remain in the product structure. If all answers are negative, the component might be coupled with another or may be removed from the product. After all components are analyzed, the minimum number of parts is achieved.

This count is the theoretical minimum number of components the system shall have to achieve operational status. Due to necessities of manufacturing, logistics, maintenance, etc, this number is usually increased. This difference does not invalidate the method. In fact, this gap strengthens that the method provides a theoretical number that must be analyzed by the design team supported by areas impacted by the product to achieve the best project for the end costumer, while improving industries' commercial margins. It must be kept in mind design team is hierarchically over the numbers.

The other objective of DFMA is to design parts easy and fast to be assembled. Thus, this means the operator does not need to spend time orienting components, using special tools for assembly or having to be helped to handle parts. Design rules to meet these requirements are to use symmetrical parts, chamfered fixes and bolts and either not to small or too large components. Examples of parts before and after DFMA analysis can be seen in figure 3. Even at on production products can be benefited of DFMA approach. Reduction on number of components and assembly time can be as high as 90% (Herrera, 1998).

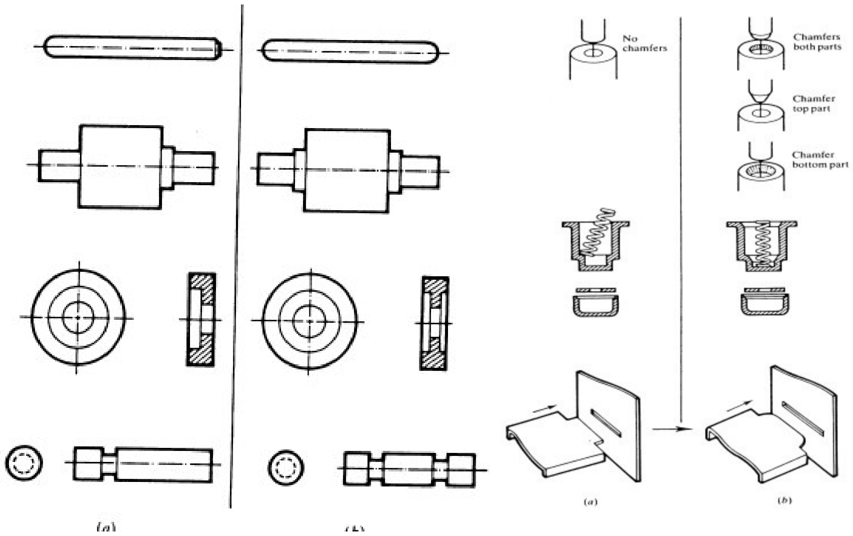

Figure 3. Parts before and after DFMA analysis (Rozenfeld and Horta, 1999).

4. INTERACTION BETWEEN POKA YOKE AND DFMA

When developing a new system, or even on post developments, designers shall follow several rules and corporate best practices to improve quality and reduce cost of a product. DFMA is one of them which is becoming popular among design teams. On the other hand, manufacturing teams are pushed to detect failure along production and solve before the product is shipped to the costumer or, even better, to the next process or station. For this purpose, dissemination of poka-yoke approach achieves virtually all kind of industries.

As poka-yoke appeared as reaction to failures occurred on the production lines, many design team are not informed the product was changed by manufacturing. On the other hand, matricial structured organizations formed for specific projects are demobilized after production starts, and the lessons learned are not fully cascaded to other departments. In most corporations communication is still a major road block to be over passed. The misalignment between areas of a company represents a serious risk for future programs, where the same mistake may be repeated. Thus, not having information flowing through departments, mainly Design and Manufacturing may allow that upgrades on the original product remove poka-yoke devices, as the DFMA questionnaire is run.

As poka-yoke devices are generic manufacturing aids, they may be located on the component, assembly line or on specific tools. It will depend on design and manufacturing team, as well as specific requirements. There is no “one size fits all” solution. Each case must be analyzed before poka-yoke implementation. Techniques are tools to help people to achieve an objective, thus they must rely on self knowledge.

When positioned on the component (see figure 4), special attention must be carried in order to accept DFMA questions when design and post development is done. Design and production team must align ideas to produce the best solution, making it easy to be manufactured not adding cost, or impacting on lowest. In the example shown below, a symmetrical component has orientation to be positioned on the next assembly. Poka-yoke method introduced a non-functional pin, to avoid misassemble. In this manner records must be kept the study, otherwise a DFMA study may remove the 26th pin. Although the addiction of a pin may result cost and a question about change the distance between pins may raised, the production process and environmental shall be analyzed. There are occasions when adding is more cost effective than changing the whole process. That is a moment when stakeholders shall meet the best solution for the company, in terms of engineering, investment on facilities and variable cost.

When devices are incorporate on production line (see figure 5) care must be taken, especially when different product flows on it, not making the failure detection jamming the system, stopping the line without reasons. Identification may be *have/not have*, or have A or B. Several devices may be used, as optical, contact or weight. On the example, two parts flow at random order. A switch is implemented on the conveyor to identify such parts. When low components passes, switch does not turn on, and part continues. When the high component passes, switch turns on and an arm pushes the part out of the conveyor, flowing to another line. This kind of poka-yoke would not be sensitive to DFMA rules, as it does not affect the product itself.

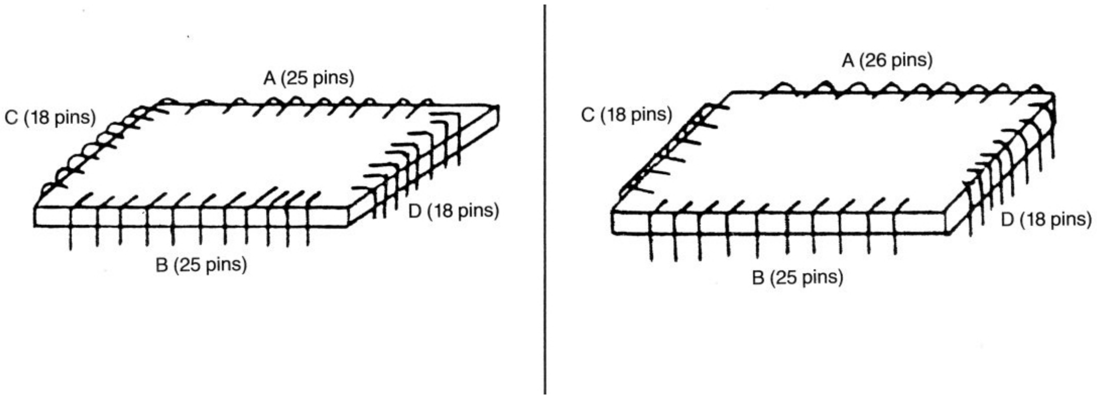

Figure 4. On component Poka Yoke (Hirano, 1988)

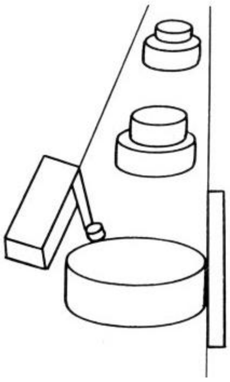

Figure 5. On line Poka Yoke (Hirano, 1988)

Finally, poka-yoke devices may be implemented on specific tools to detect or approve the part. Examples can be screw drivers with torque sensors, tools with counters that only allow the part to proceed after specified number of operations. This application is especially useful and important when several identical operations must be manually done in a single part or assembly. It avoids the operator to keep attention on the number, and not on the operation itself. When used on critical and safety operations it provides to the company a double check on the operation. On automotive industries, vehicle only moves to next station after wheels and seat belts anchorage bolts are torque correctly, two critical-to-safety operations. As the prior example, robust-to-DFMA poka-yoke is implemented on the process, being independent about DFMA.

When product development became integrated, one of the main differences is the joint work of design and manufacturing teams. The walls that separated Design and Manufacturing were broken. This objective is still pursued from small to large companies, but still not fully accomplished. The idea of integration is to have both teams working on design phase, not to have problems when producing. When implemented, benefits of Poka-Yoke and DFMA will be summed, providing a quality product, ease to be produced and free of manufacturing failures.

One of the objectives of DFMA is to make components easy to be assembled, while poka-yoke objects to assemble parts correctly. In other words, both methods were developed to produce more robust products. In this matter, methods are compatible, though acts with different strategies. The seek for reducing the number of components cannot be blindly done removing any part which does not answer YES to at least one of the three questions. Thus, the theoretical minimum number of parts is a count that may, and not must, be pursued. The mission of a company is to profit and delight consumers with cost effective and quality products, which must be done using all techniques available for engineers. Thus, Poka-Yoke and DFMA are tools that must be always used on concurrent designs.

When poka-yoke is installed at production facilities, it is clear it is independent from any DFMA analysis. Thus, only poka-yoked components may be carefully designed not to conflict with DFMA premises. The usage of both techniques is aimed to facilitate production processes, reducing overall costs for the company.

5. CONCLUSIONS

In this paper, two methods aimed to improve manufacturability of products were presented. Although the use of Poka-Yoke and Design for Manufacturing and Assembly methods sounds to be incompatibles in a first sight, it was showed their objectives are similar: produce high quality products and increase company´s profitability. The intention to use them in parallel reflects the challenges imposed by the globalized market, which pushes all kind of industries, as well service providers, to deliver a better and more valuable product. The efficiency achieved by the synergy of the two methods can be proved by the reduction on reworked parts and assembly time, prior and after the implementation. Although theoretically simple, this measurement is not easy to be implemented in an operating system. Teams must keep in mind their work may not be viewed in the next day, and the whole company must be educated to think before act. Design team must have time to project and re-project parts along concept and refine phases, and manufacturing team must support this phase, and when failures happen on production, technical solutions must be found, in a work done by design and manufacturing teams, working together.

Other challenge for the engineering teams is to implement these tools, transforming traditional differences between design and manufacturing teams in synergy forces.

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