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Technical paper

A framework for assessing poka-yoke devices

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ABSTRACT

This study introduces a framework for assessing poka-yoke devices (PD), encompassing both those designed for quality control (referred to as quality PD) and those designed to control hazards to health and safety at work (referred to as safety PD). The framework assesses the processes of the design, operation and maintenance of PD, rather than the outcomes of these processes. The development of the framework involved three stages: (a) defining 15 attributes of PD, identifying those that provide fail-safe characteristics and those that inform best practices in design, implementation and maintenance; (b) defining what the set of evidence and what the sources of evidence should be for assessing the existence of each attribute; the sources include documents, interviews, observations and a meeting to discuss the results of the assessment with company representatives; and (c) defining a scoring system to express the results of the assessment. The application of the framework is illustrated by means of assessing four PD; two of them being concerned with quality and two with safety.

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1. Introduction

The principles and practices of lean production (LP) have been increasingly used by a number of industries [1,2]. This study emphasizes the use of poka-yoke devices (PD), a LP practice especially tailored to eliminate the production of defective parts, complementing statistical process control techniques [3,4]. Since this term started being disseminated in the West in the context of spreading the Toyota Production System [5], PD has been a topic of interest, mostly among practitioners, due to the apparent simplicity of how they function and their intuitive design features [6]. PD have been used in a variety of contexts, such as construction, health care and information technology, but not necessarily associated with LP implementations [7–9].

However, there seems to be a scant academic interest in this topic, conveying the misleading message that the design and operation of PD can be explained by common sense [6]. In fact, similarly with other important LP practices (e.g., kaizen and visual management), the literature on PD is, to a great extent, directed to practitioners [10]. As a result, the attributes of PD are presented in a fragmented way over a number of studies [5,7,9,11], without being integrated into scientifically validated frameworks for designing and assessing them. In this study, the focus is on the development of a framework for assessing the use of PD. No reference was found on methods, which had been tested and validated in real-world settings, which could be used for assessing the use of PD.

From both a practical and theoretical perspective, the need to develop a framework for assessing PD is part of the need to develop methods for assessing the use of lean practices. In fact, compared with the efforts made to address "how to become leaner", the issue of "how lean the system is" has received less attention [12]. Although a number of methods have been drawn up to assess the extent to which a company adopts lean principles [12–14], fewer methods [15,16] aim at assessing the use of lean practices, the implementation of which takes place directly and visibly on the shop-floor (e.g., PD). Survey has been the preferred strategy for assessing the use of lean practices, aiming at investigating large samples of companies [16–20]. While these surveys have merits, they tend to be of little use as tools to companies that aim at assessing how their particular lean practices are performing.

Thus, similarly with previous studies on the assessment of lean practices [15], this study adopts the method of auditing as an alternative. This method is well-known in most industries, combining both qualitative and quantitative assessments [21], which can provide more pragmatic insights for individual companies, in comparison with those provided by surveys. An audit is a systematic, independent and documented process to obtain evidence and to assess them objectively, measuring the extent to which audit criteria are met. Auditing allows the gap between desired and actual performance to be identified, as well as to enable the assessment of information that can be used to improve performance [22].

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The attributes encompassed by the framework proposed by this article are applicable both to PD designed for quality control and to those designed to control hazards to health and safety at work (H&S). This integrative perspective between quality and H&S might be considered as a distinctive feature of the proposed framework, as both companies and the academic literature usually deal with each type of PD separately. According to Stewart and Grout [6], this is due to the fact that, typically, researchers and practitioners devoted to quality control have little technical knowledge of H&S, and vice versa. The application of the framework is exemplified by means of applying it so as to analyze four PD: two of which are concerned with quality and the other two with safety.

2. Definition of poka-yoke

The literature presents a number of similar definitions of poka-yoke, even though they use different key terms and are often far from precise. According to Shingo [5] a poka-yoke is a mechanism for detecting errors and defects, which inspects 100% of the pieces, working independently on the operator's attention span. To Grout [7] a poka-yoke is the use of process or design features to prevent errors or the negative impact of errors. Middleton [23] defines poka-yoke as the systematic practice of eradicating errors, by locating their root cause. Plonka [24] considers that a poka-yoke is a mechanism for detecting, eliminating, and correcting errors at their source, before they reach the customer. Other studies simply define a poka-yoke by means of examples, either by simply substituting this label with others, such as sensors and jigs, or by translations such as mistake-proofing [25] or error-proofing [1]. Such synonyms draw on concepts that are intuitively meaningful in the sense that everyone associates something with them, so they feel they understand them [26].

In this study, based on the above mentioned definitions, a poka-yoke is defined as a device that either prevents or detects abnormalities, which might be detrimental either to product quality or to employees' H&S. A poka-yoke might be considered as three types of devices [27]: (a) physical, if they block the flow of mass, energy or information, and do not depend on users interpreting them (e.g. a wall); (b) functional, if they might be turned on or turned off due to an event (e.g. a lock or a password), without depending on user interpretation; (c) symbolic, if they require interpretation, yet are physically present at the moment they are necessary (e.g. a safety sign). Immaterial devices [27] do not constitute PD, since, regardless of their demanding user interpretation, they are not physically present at the moment they are necessary (for example regulations and organizational culture).

It is worth emphasizing two implications of the definition this article adopts: (a) PD might demand interpretation from operators, if they comprise symbolic devices; (b) PD can be either proactive, if they prevent abnormalities, or reactive, if they detect abnormalities. From a quality perspective, the difference between proactive and reactive lies in the type of inspection performed by the PD [5]: (a) source inspection, which avoids the occurrence of a defect (proactive PD); (b) self-inspection, which detects a defect in the very operation in which it is generated; (c) successive inspection, which detects a defect in the operation following the operation in which it was generated; (d) judgment inspection, which detects a defect two or more operations ahead of the one it was generated. Inspection types (b), (c) and (d) are reactive ones, since they detect defects, rather than prevent them. While a PD might be integrated within any operation (e.g., transportation, processing, inspection, etc.), all PD perform at least one out of the four types of inspection previously mentioned [5]. From a safety perspective, proactive PD are those that avoid a human-machine interaction that may cause an accident, while reactive PD are those that contain the energy released by this interaction after it has happened.

Another well-known classification of PD, proposed by Shingo [5], concerns the one that differentiates a control function from a warning function. The control function requires there to be one or more of the following features: (a) it turns off the machine, or physically blocks the continuity of a manual process, once it detects the abnormality; (b) it does not allow the operator to choose how to carry out the task, but obligates him to perform it correctly; (c) it automatically excludes defective parts from the production flow. The warning function means that the poka-yoke signals, by means of symbolic devices (e.g. lights and/or audible alarm), the occurrence of the abnormality [5].

3. Research method

3.1. Overview of the research method

The development of the framework followed three stages: (a) defining the attributes of PD; (b) defining evidence and sources of evidence to assess the existence of each attribute; (c) developing a scoring system to express the results of the assessment. After being designed, the framework was tested by assessing four PD. Two of them, deemed quality poka-yoke 1 (PQ1) and safety poka-yoke 1 (PS1) were assessed in company A. Another quality poka-yoke (PQ2) was assessed in company B. Both companies A and B are suppliers of auto-parts for major car manufacturers, and they had adopted LP as a formal corporative policy. In order to check the applicability of the framework in a non-manufacturing and non-lean environment, a second safety poka-yoke (PS2) was assessed in a construction company (company C).

3.2. Definition of attributes of PD

The definition of the attributes was based on five criteria:

(a) the attributes should be, as far as possible, generalizable both for safety and quality PD;
(b) the attributes should take into account the whole life-cycle of the PD, ranging from its design process to its replacement;
(c) the attributes should be concerned with PD used in the manufacturing of products, rather than being concerned with PD used in other phases of the life-cycle of a product, such as its design and use by end customers. It is worth noting that this criterion is not contradictory with the previous one. While criterion (b) states that the whole life-cycle of the PD should be taken into account by the attributes, criterion (c) states that the attributes should consider a specific stage of the life-cycle of the products inspected by PD (i.e., the stage of manufacturing);
(d) the attributes should be consistent with the concept of poka-yoke presented in section 2 of this article (definition of poka-yoke), while recognizing that they are not necessarily fail-safe, even though this is the ideal situation;
(e) the attributes should be grounded on a sound theoretical basis, mostly drawn from the fields of human factors and LP.

Based on these criteria, as well as on previous studies [5–7,9,11,23,24], 15 attributes of PD were defined. They were grouped in two categories (see Tables 1 and 2): (a) eight attributes that assess if fail-safe characteristics exist; (b) seven attributes that assess the existence of best practices for the design, implementation and maintenance of PD.

It should be noted that, even though all attributes listed in Tables 1 and 2 are complied with, labeling a poka-yoke as 100% fail-safe is an over-simplification. The attributes are mostly concerned

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