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Implementation of Plan-Do-Check-Act (PDCA) Cycle for Product Quality Management: Evidence from a Manufacturing Enterprise in China

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Abstract: In the market with increased competition and a large number of choices, it is necessary for enterprises to improve the existing standards of product quality to meet the customer demand and achieve sustainable development. As for the manufacturing enterprises, continuous improvement supports in reducing defective rate of products and safety risks, which enhances the overall product quality. This paper discusses a case study in implementing Plan-Do-Check-Act (PDCA) to improve product quality of compressed natural gas (CNG) cylinders in a manufacturing enterprise in China. The outcome is the enterprise has successfully reduced the defective rate of the products from 50% to 27% and improved the production efficiency.

Keywords: Plan-Do-Check-Act (PDCA); Product Quality Management; Continuous Improvement; CNG Cylinder
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1.Introduction

With the advancement of urbanisation, the issue of environmental protection is becoming increasingly obvious, which has aroused great concerns from all countries (Prashar, 2017). According to Hao et al. (2016), vehicle emission has been highlighted in the various factors of urban environmental pollution and the natural gas vehicles are being developed for the replacement because of its low emission and cost-saving. One of most important products of manufacturing enterprises for automatic vehicles is the compressed natural gas (CNG) cylinders which will become the direction for the automatic cylinder in the future (Khan et al., 2015). In the attraction of the bright prospect, many manufacturing enterprises in China have entered the market to produce CNG cylinders. However, there remain many issues of this type of automatic products, and some enterprises even put substandard products on the market for the immediate profits, which seriously threatens the safety of consumers and the public (Majernik et al., 2015). As a high-pressure container, CNG cylinder may cause explosion accidents if the quality is below the standard or have defects. Therefore, quality has become one of the critical success factors among manufacturing enterprises and the winner is supposed to seize the opportunity that meet customer demand through the most reliable methods (Maminai & Barbados, 2011; Goetsch & Davis, 2014; Realyvásquez-Vargas et al., 2018; Potkany et al., 2022).

Plan-Do-Check-Act (PDCA) cycle, also known as the Deming cycle, was proposed by Edwards Deming as an expert of quality management (Sokovic et al., 2010; Nguyen et al., 2020). In the process of total quality management (TQM), PDCA cycle can be regarded as a basic approach for continuous improvement. This method is applicable to a wide range and can be implemented to the product quality management and reducing defects of manufacturing products. Thus, in this paper, the researcher will first have a literature review related to the content of quality management and PDCA cycle and adopts a case study of implementing PDCA cycle on product quality management of CNG cylinders from a manufacturing enterprise in China.

2.Literature Review

2.1 Quality Management

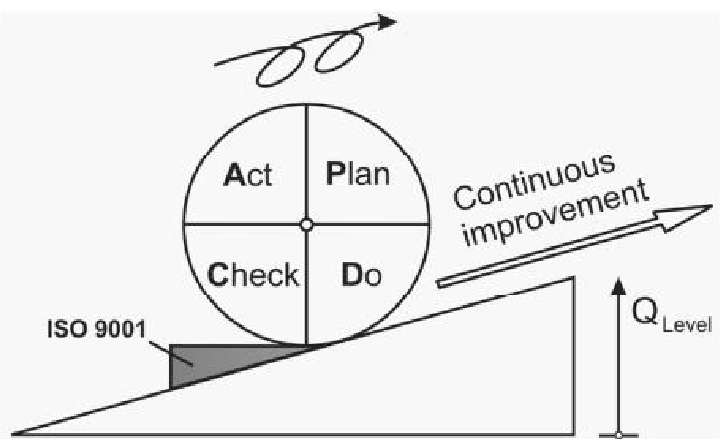
Quality is one of the objectives of quality management. According to (Goetsch & Davis, 2014), it is important that the enterprises should take quality into account for decision-making because the high quality of products bring the business profitability and promising development of the enterprises while low quality may result in deficit even loss of market. Thus, if the enterprise wishes to keep in sustainable development, it needs to improve the quality of the products and services. Lo et al. (2007) state that the rejection rate and a variety of consumption can be reduced in the high-quality manufacturing process, which save the cost in an invisible way and bring economic benefits to the enterprises.

According to Linderman et al. (2004), quality management can be defined as a method which the organisations use to continually improve the quality of products and services as well as make sure the result and the process of improvement have met the expectation of customers and other stakeholders. On the micro-level, the survival and development of enterprises cannot be separated with product quality because the customer requirement on the product quality has become higher as the time changes. Therefore, Jagusiak-Kocik (2017) states that the effective improvement of product quality will greatly improve the market competitiveness of enterprises and customer satisfaction. Any enterprise with social responsibility will regard quality management as a necessary measure to protect the interest and the security of the customers. On the macro-level, the enterprises should strategically consider the improvement of product quality in the international context in terms of the economic globalisation. The low quality and its negative impact should be avoided because the enterprises represent the image of the original countries to some degree. Additionally, total quality management (TQM) is the effective way of management that regards the quality of products and services as the core and total employee involvement as the basis to reach sustainable operation through benefiting the customers and all members in the organisation (Kaynak, 2003).

2.2 Plan-Do-Check-Act (PDCA) Cycle

PDCA cycle or Deming's cycle is regarded as one of the basic approaches of TQM (Sokovic et al., 2010; Nguyen et al., 2020). It divides the quality management into four steps including Plan, Do, Check and Act. It aims at explaining that the business process should be continuously improved and identifying the specific parts of the products which need to be improved. As is mentioned by Ning et al (2010), the PDCA cycle can be applied to the improvement processes in enterprise management through the dynamic round of Plan-Do-Check-Action. Omens (2006) add that the PDCA cycle is the essence of TQM activities, and it can be regarded as the common working process of the organization to develop and focus on the organisational needs.

Figure 1 PDCA Cycle for Continuous Improvement



Whilst the cycle can be applied to a wide range of contexts as a framework to solve the issues of quality management (Pietrzak & Paliszkiewicz, 2015). For example, Prashar (2017) studies the improvement of energy management system in the energy-targeted small and medium-sized companies based on PDCA cycle. Jagusiak-Kocik (2017) carries a case study of implementing the cycle to product development in the plastics processing industry. Hasan & Hossain (2018) suggest the cycle can be used to improve the teaching quality of engineering experiment in the universities. As is shown in Figure 1 by Sokovic et al., (2010), PDCA cycle typically consists of four phases for continuous improvement of product quality.

Phase one: Plan. In this phase, the organisations should set up the targets and objectives of quality management as well as prepare the plan for it. There are normally four steps in detail: (1) Analyse the product quality and identify the issues. (2) Discuss the causes of product quality problems. (3) Find and target the main factors and causes. (4) Provide the solutions and plan direct at the main factors and predict the result of implementation.

Phase two: Do. This phase requires the organisations to implement and test the specific measures based on the plans and targets which have been proposed in phase one. The do phase is also regarded as step five in the cycle.

Phase three: Check. This phase or step six is to compare the implementation results with the proposed plans to check whether the implementation and effect of the measures are consistent with the expected results and objectives.

Phase four: Act. This phase includes two steps: (1) Summarise the achievements and lessons of the implementation. Successful experience will be applied in the future while the same issues should be avoided happening again (2) Put the issues which have not been solved in this cycle to the next round and begin to develop the quality plan for the next phase.

2.3 Benefit and Drawback of PDCA Cycle

The benefits of the PDCA cycle have been widely marked in the relevant studies. One is that the cycle is an iterative process which can be used many times to resolve the issues (Sokovic et al., 2010). The value of the cycle cannot be ignored as a standard tool of TQM. The employees in the organisations will put efforts to the organisational improvement through different position roles if they are aware that there is a standard process for improvement to follow. The other is that a distinct competitive advantage can be brought by the PDCA cycle (Jagusiak-Kocik, 2017). The business productivity and customer satisfaction of the organisations will increase with the implementation of the dynamic cycle. Another important benefit of the cycle is risk control. According to Alyoubi et al. (2017), PDCA cycle is designed to mitigate the mistakes and faults in the process of performance improvement because the changes will be tested in a small range before being taken in the whole organisation.

Although there are few drawbacks of PDCA cycle can be found, it still exists in the process of implementation. Ning et al. (2010) mention that the PDCA cycle focuses on total involvement of the employees, but the current organisational culture may be challenged by applying the multi-step process into the organisation. Also, it takes a relatively long period of time to plan changes which are ineffective for dealing with urgent problems.

3.Product Quality Management with PDCA Cycle in Enterprise F

3.1 Quality Management System of Enterprise F

Enterprise F is a manufacturing enterprise located in Shanghai and mainly engaged in the research, development and production of aerospace and civil composite materials. The main products developed by the enterprise are applied in the space field such as satellite carrier rocket spacecraft and the field of high-speed railway and vehicles. The enterprise regards quality as one of the most important factors in the production process as well as has passed many attestations including ISO9001, ISO14001 and TS16949. Currently, the products in the civil aspects mainly encompass the composite cylinders for medical use and the compressed natural gas (CNG) cylinders for natural gas vehicles. According to the confidential, the data of quality improvement in 2017 is analysed in this paper.

In the process of further development, enterprise F constantly absorbs the lessons and experiences of management from domestic and international enterprises as well as accept the advanced management vision to its own management. Combined with the specific situation of the company and the standard of TS16949, the requirements for manufacturers in the automobile industry to implement ISO9001, enterprise F has designed its own quality management system (QMS) which emphasises the quality as the basic guarantee to improve management process. The company believes that the establishment of a scientific and reasonable QMS is the positive way of taking social responsibility. The QMS of enterprise F is formulated based on PDCA cycle and the process has been divided into four phases which include preparation and targets setting, QMS strategic planning, implementation and the phase of inspection and assessment.

3.2 Implementing PDCA Cycle for Quality Improvement of CNG Cylinders

3.2.1 Plan

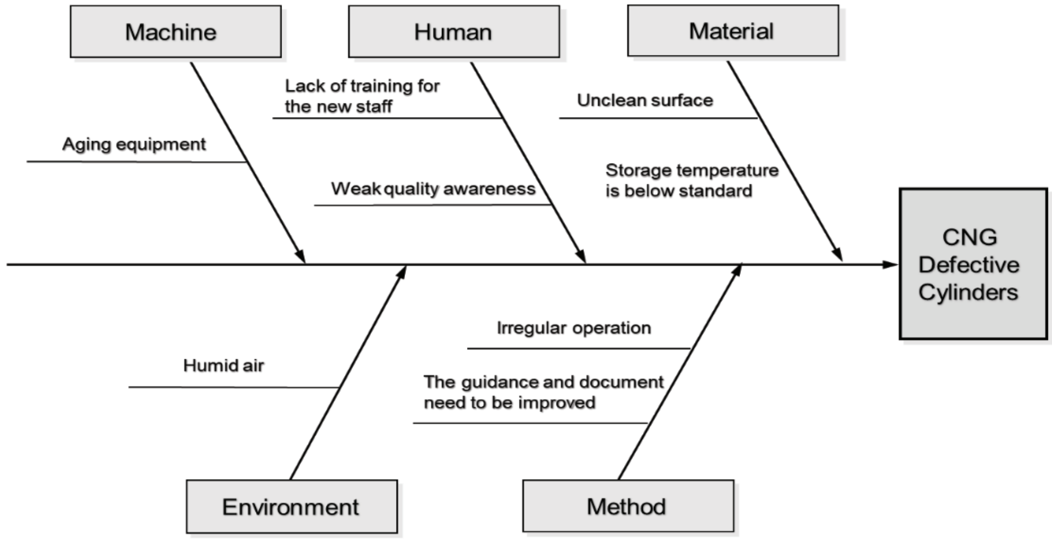
Although there are many factors can affect the quality of CNG cylinders, the minority of them are important. According to the data of defective cylinders, 50 products have been marked below the standard in the total figure of 808 and the defective rate is 6.2% in March 2017. As is shown in Table 1, the main factors to cause defective products are front pits and thread wears which are 36% and 24% respectively. As a result, these two factors should be focused on the improvement process of CNG cylinders.

Table 1 Defective CNG Cylinders of Enterprise F in March 2017

Problems	Numbers	Percentage (%)
Pits in the front	18	36
Bottleneck capillary crack	5	10
Thread wears	12	24
Air leakage	2	4
Sticky surface	10	20
Others	3	6
Total	50	100

In terms of the factors to cause the quality problems of the cylinder are complex, a fishbone analysis is considered in this study. According to Luo et al. (2018), the fishbone diagram or Ishikawa diagram is regarded as a common tool of management that can be used to find the cause and effect of quality problems, analysing the relationship among the elements to affect the quality. Thus, the researcher has come up with a fishbone analysis based on the provided information to find the factors which result in the quality problems of CNG cylinders (See Figure 2).

Figure 2 Fishbone Analysis for CNG Defective Products



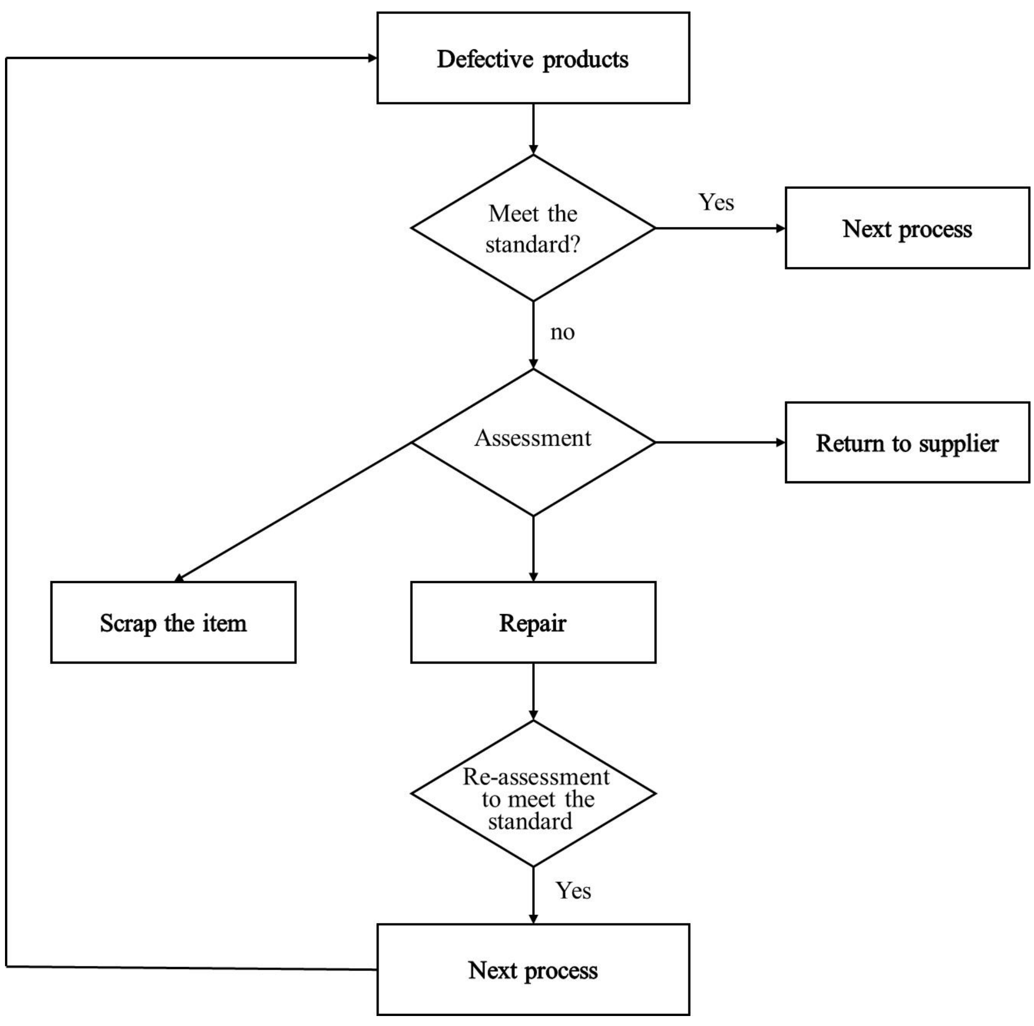
3.2.2 Do

According to Goetsch & Davis (2014), quality control in the production process is an important part of product quality management to assure the quality of the products. In the entire process of producing CNG cylinders, quality control determines the quality of cylinders as well as indirectly reflect the level of quality management of the company. Thus, the implementation has been taken on the main factors in terms of the identified problems in stage of plan (See Table 2). Also, enterprise F considers that the existing defective products should be incorporated into a unified management process to make sure the high-pressure vessels are under control. Figure 3 illustrates a flowchart process of managing the products below the standard in enterprise F for quality improvement.

Table 2 Strategic Plan for Mitigating Quality Problems of CNG Cylinders

No	Problems	Statements	Requirements
1	Sticky surface of thread	· Deploy staff to clean the items · Repurchase it every year	List on the working plan
2	Pits on the products	· Handle with care in delivery · Put the soft materials on the · corners of the working area	Complete by next month
3	Storage temperature	· Need to be checked by the · inspectors every day	List on the working plan
4	Documents improvement	· Update the inspection records	Complete by next month
5	Week awareness	· Provide systematic training on the methods of · quality control to the staff	Concise plan and content

Figure 3 Process Flowchart of Defective Products



3.2.3 Check

In this stage, it is important to check the results after having improved the quality control of the production process of CNG cylinders as well as taken measures on the factors to cause defective products. There are 27 of 1010 products have not met the standard and the defective rate is 2.7% in the next month which is April. In Table 3, the main factors are air leakage and bottleneck capillary crack which is 25.9% and 37.1% respectively in this time. Compared to data in last month, the main quality problems which are pits and thread wears have been efficiently improved and even the issue like the sticky surface has been fully solved. Thus, the results implied that enterprise F has taken the successful implementation on the product quality improvement.

Table 3 Defective CNG Cylinders of Enterprise F in April 2017

Problems	**Numbers**	**Percentage (%)**
Air leakage	7	25.9
Bottleneck capillary crack	10	37.1
Pits	3	11.1
Thread wears	2	7.4
Others	5	18.5
Total	27	100

3.2.4 Act

The quality of the CNG cylinders is effectively improved after the implementation and the defective rate has declined from 6.2% to 2.7% in the comparison between two months. The problems of pits and thread wear of CNG cylinders have obviously reduced. Based on the systematic training of quality management, new staff and the employees with weak awareness of quality have fully understood the quality improvement requires total involvement and collaboration rather than only the work of the quality department. Also, according to Table 3, the comparison has found the air leakage and bottleneck capillary crack become the main factors to affect the quality of CNG cylinders which need to be taken to the next round of PDCA cycle.

To summarise, enterprise F has successfully implemented the quality improvement on CNG cylinders based on the PDCA cycle, which reduce the defective rate of the products from 50% to 27%. In the entire process, the company has found the factors which cause defective products as well as made the targeted plans on the main factors for the improvement. Finally, the enterprise has reached the expected goal of quality improvement, and the production efficacy has increased due to defective rate has declined.

4.Conclusion

In conclusion, the PDCA cycle is closely related to the process of product quality management (Goetsch & Davis, 2014). This dynamic cycle can be applied to various types of process management for the enterprises in the manufacturing industry to figure out the causes and factors of problems and promote continuous improvement (Sokovic et al., 2010). In the case study, the quality of CNG cylinders of enterprise F reduce the overall defective rate of product from 50% to 27% with the implementation of PDCA cycle. The main factors to cause the defective products to have reduced with the overall percentage of the pass has increased, which has reached the expected target. However, besides the positive outcomes of the product quality management, problems always appear in the process of continuous improvement. As is stated by Steinfeld (2004) that the enterprises intend to maintain the status quo and stop to move ahead when some effective results of improvement are achieved or because of the project progress and cost pressure. As a result, these troubles may reduce the efficiency of implementing the PDCA cycle. Therefore, it is important for manufacturing enterprises to put more efforts and overcome the main obstacles which constrain the quality management and business benefits. Based on the PDCA cycle, the processes in a manufacturing enterprise have become controllable, which supports the continuous improvement of product quality (Alyoubi et al., 2017).

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no

Conflict of Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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