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TRIZ methodology for applied chemical engineering: A case study of new product development

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ABSTRACT

Innovation in chemical engineering is becoming more challenging in developing products that have different applications. This maximizes the chemical engineering capability of commercialization of possible potential product from existing resources. However, systematic and reliable methodology is critically needed for chemical engineers to bring innovation in their product, especially through solving problem and forecasting. At present, there is no systematic methodology and framework to provide chemical engineers with problem-solving approach and concurrently to develop a new product using forecasting. In an attempt to contribute to this critical area, this paper proposes TRIZ methodology and framework for problem solving and forecasting in product development. The methodology and framework guide chemical engineers to create product innovation through problem solving with contradiction and forecasting using strategic TRIZ tools. The approach is illustrated on an automotive case study of liquid bumper technology and diverged the technology generic function to develop other new products and applications. The case study shows a systematic approach in solving contradiction in product development and how to identify potential and feasible common products and adopt similar technology with a generic function to create product innovation for wider applications.

1. Introduction

In this competitive world of globalization, industries are struggling to improve their products and processes for the dynamic and high expectations from customers. The chemical industries need to be ahead of the other competitors to achieve sustainability and always maintain the gaps through various means. The most common challenges in almost all chemical industries are manufacturing products with the lowest cost and generating profit from market sales. However, the chemical industries can move their focus to the cost challenges if they are able to produce innovative products that will bring a higher value to the customers, even if the cost is expensive (Klein-Marcuschamer et al., 2012). Successful competitive industries are not only able to improve their product costs, but also able to bring a high value profit through their product innovations.

As the improvement of product cost and innovation are important to the competitive chemical industries, it is critical for the industry to have a strong and reliable approach

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and method to support the product innovation and development. On top of that, the most important factor in ensuring the success of delivering the targeted goals is the chemical engineer (Chesbrough, 2013). Both engineer and method should provide the idea and solution in product cost reduction and innovation. In the real situation, reducing costs and developing innovations are not as easy as perceived. The challenge consists of problems that have various levels of complexity, constraints and limitations that represent various levels of difficulties (Kiss and David, 2012). Therefore, it is important for the chemical engineer to have an effective method to ensure that the targeted results are achieved and the industry's competitiveness is improved.

In the chemical engineering field, the current approach or method used by the engineer depends on specific conditions. The first condition is to improve the products within the boundaries of resources and technical expertise. This focuses on a lower profit margin, a reduced time to market, a decreased product life cycle, environmental constraints, sustainable development, etc., through the optimization approach (Christensen, 2013). The second condition is improving the product that goes beyond the current knowledge of chemical field, a different field of technology, processes and technical expertise (Davenport, 2013). Most of the innovations in chemical engineering are involved in this second type of condition. This brings huge challenges for chemical engineers to grasp a new type of knowledge to be adopted into their new ideas or solutions for their product.

Cutlip and Shacham (1999) developed an article on problem-solving in chemical engineering. They explained that the complexity of chemical problem-solving approach require the use of numerical language and software. However, the problem-solving scope only covers on optimization such as to derive the model equations for the problem at hand, find an appropriate numerical method to solve the model, write and debug a programme to solve the problem using the selected numerical algorithm, and analyze the results for validity and precision. There is a lack of literature that focus on problem-solving methods in the chemical engineering field (Cutlip and Shacham, 1999). Furthermore, the lack of properly framed standard problems in various engineering disciplines is accompanied by a lack of faculty interest in the use of new tools and the creation of appropriate problems that utilize other tools. Therefore, there are critical needs to have a proper guide and reference for the chemical engineers to use for problem-solving in their products.

In the education perspective of problem-solving for chemical engineering, Woods et al. (2013) have identified that chemical engineering graduates did not possess sufficient problem-solving skills before entering the industry. Even though the teaching and learning process in the university is excellent, when the students are given the problem-solving tests using the open-ended answers type of questions, they were unable to execute them successfully. The study has found that the problem-solving course given to the chemical engineering student has no significant effect to the students' performance in problem-solving. The study suggested enhancing the programme knowledge with more effective problem-solving tools to apply besides brainstorming (Woods et al., 2013). The programme also progressed by adopting interdisciplinary learning as improvement that not only focuses on the depth of chemical engineering knowledge but also includes basic knowledge from other disciplines. Therefore, to have a systematic, effective and cross-disciplinary methodology in problem-solving, it is critical for the engineers, especially in the chemical engineering field.

Meanwhile, in the product competitive development, the chemical engineering industry has a challenging task in presenting its products to the market. The product evaluations are moving at a rapid pace to meet the market's demands and trends (Cussler and Moggridge, 2011). The chemical industry is struggling to produce cheaper products and bring higher values to the product evolution. This is the major part of competitive problem for the industry to solve. In this condition, the industry is looking for a solution in product innovation with a low cost. Therefore, the problem-solving capability is required for product competitive development and innovation. In the current condition, the chemical engineering industry shows a high constraint in innovation and creativity compared to other engineering fields (Robles et al., 2009). In this context, it is critical to have effective methodologies and tools for chemical engineers to develop interest in product development and innovation for the competitive market. Despite several issues highlighted in problem-solving and innovation methodologies in the chemical engineering field, we proposed a methodology together with tools to help chemical engineers to improve product competitiveness. The proposed methodology is called the 'Theory of inventive problem-solving' or commonly known as TRIZ (a Russian language acronym for Teoriya Resheniya Izobreatatelskikh Zadatch).

1.1. TRIZ and chemical engineering industry

In recent research, TRIZ has been used to solve inventive problems in diverse engineering industries. Chemical engineering industry is one of the industries that are starting to apply TRIZ. Through chemical engineering, solutions are developed via either a new product or process development (Coutinho et al., 2005). TRIZ has been found to be able to assist both product and process developments. An example of a case study for a new product development is about an innovative diaper. With the guide of the TRIZ tool termed the Trends of System Evolution, a biodegradable diaper was developed (Vicente Chulvi and Vidal, 2011). A new and biodegradable chemical material used for this diaper was polyolefin plastic.

Another TRIZ case study is a new process development. The efficiency of biomass gasification was improved using the 40 Inventive Principles of TRIZ (Ferrera et al., 2012). Both products were developed to solve a specific problem. The first product is related to the problem of disposal and accumulation of non-biodegradable diapers in the environment. In the second problem is related to processes, in which the existing biomass gasification is not efficient and consequently consumes more resources.

These two case studies demonstrated the conventional approach of using TRIZ to solve a problem. Firstly, a specific problem is generalized. Then, general solutions are correlated to the general problems using some of the TRIZ tools. Finally, the industry expert would develop new specific solutions that solve the specific problems. These four phases are termed as the conventional TRIZ framework (Lim and Teoh, 2010). This research proposed an inverse of the conventional TRIZ framework for the application in chemical engineering as shown in Fig. 1. Chemical engineers are often tasked to use a specific chemical to solve a problem. The more problem the chemical can be applied as solution, the higher its value will be.

Instead of starting with a specific problem, it is proposed that a specific chemical should be chosen first. This specific