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Application of TRIZ to Solve Automotive Braking System Problems

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ABSTRACT

In today's world, there is a great demand of creative ability in product development. To cope with this situation it is important that new efficient creativity methods, tools, and techniques, be made available to predict and roadmap future generations of products and technologies. In the current status for identifying problems and its root causes in many organizations including, Malaysia's automotive manufacturing industry doesn't always give us the ideas we need to find a solution. Thus, the future for the improvement of technology and industry is the merger of quality with creativity and will depend on how people utilize and extend creativity tools and methods. Theory of Inventive Problem Solving (TRIZ) methods can be used as a powerful tool for igniting the creative imagination to solve simple and difficult technical and technological problems more quickly and with better results. This paper gives firstly, a brief overview of TRIZ methods and tools .Secondly, a case study was carried out related to manufacturing real life to provide a guide to utilize TRIZ theory and to develop Innovative solutions in the automotive industry.

Keywords*: *Theory of Inventive Problem Solving (TRIZ), Creativity Tools, Automotive Industry, Innovative.

1. Introduction

Today, under the trend of survival competitions among enterprises there are, numerous and a variety of problem-solving tools, methods, and techniques have been used in the organizations, despite the effective and widely used for some of them, many companies are still looking for significant solutions that can continually adapt their products efficient, development processes and enhance innovation capability. In Malaysia's automotive industry tools such as, Define-measure-analyze-improve-control (DMAIC) and Plan-do-check-act (PDCA) are commonly used as a "Standard" quality improvement; these tools have always enhanced by methods such as brainstorming as a key method for generation idea, analyzing failures and finding solutions to problems in product, service development [1]. Brainstorming method is quick to learn and easy to use; But this method doesn't always work effectively, since the solutions usually taken based on the accumulation of experience, in some cases, engineers may not have sufficient experience to solve complex problems. However, when applied to challenging engineering and manufacturing problems and the solution lies outside the experience of the team this tool remains too intuitive and it's unable to motivate creativity. Thus, the method can create several ideas but most of them are not useful when solving contradiction problems [2].TRIZ inventive problem solving methods can help in situations where unexpected problems have occurred and where the source or cause of the problem is unknown. TRIZ can play an important role in facilitates a collaborative manufacturing environment for the team members, and makes up for the lack of design experience for new processes and products. TRIZ applies to both continuous improvement and development of new products and services because continuous improvement requires solving current problems, and development requires finding a way to solve customers' problems. This paper is organized into two parts. The first part introduces the TRIZ Philosophy, its basic concepts and its major tools and techniques and highlights the effects of TRIZ in the future of the worlds, industries. The second part an actual case study shows how TRIZ can be effectively used as a creative problem solving methods.

2. TRIZ Scheme of Problem Solving

TRIZ a Russian acronym for "Theory of Inventive Problem Solving" is a different kind of creativity system and one of the most powerful inventing methodologies; it is based on a derived method that originated for the examination of the world patent collection and analysis of creative solutions to past problems. It originated in the late 1940s, in the former

Soviet Union, as an attempt to develop a method, which would support a process of generating new ideas and finding solutions in a systematic way [3]. A traditional approach toward solving problems is by directly moving from a specific problem to finding a specific solution. However, there are many cases where this approach may not work due to contradictions or conflicts, which prevent good solutions from being generated. In most cases, the solution using the normal problem-solving process will be in the form of a compromise or finding. The strategy of TRIZ resolve problems is different from the other methods of problem solving. The basic strategy of TRIZ is that "In most cases the problem we are facing now, has been already faced by many other people at different times, at different places and in different situation, and most likely been solved in different ways." The focus of the TRIZ approach, as shown in Figure 1, is to "find the solution from those solutions," and it allows connecting the problem to a standard problem and suggesting a standard solution, which provide the direction to be followed in order to determine the best solution for the problem overcoming contradictions [4].

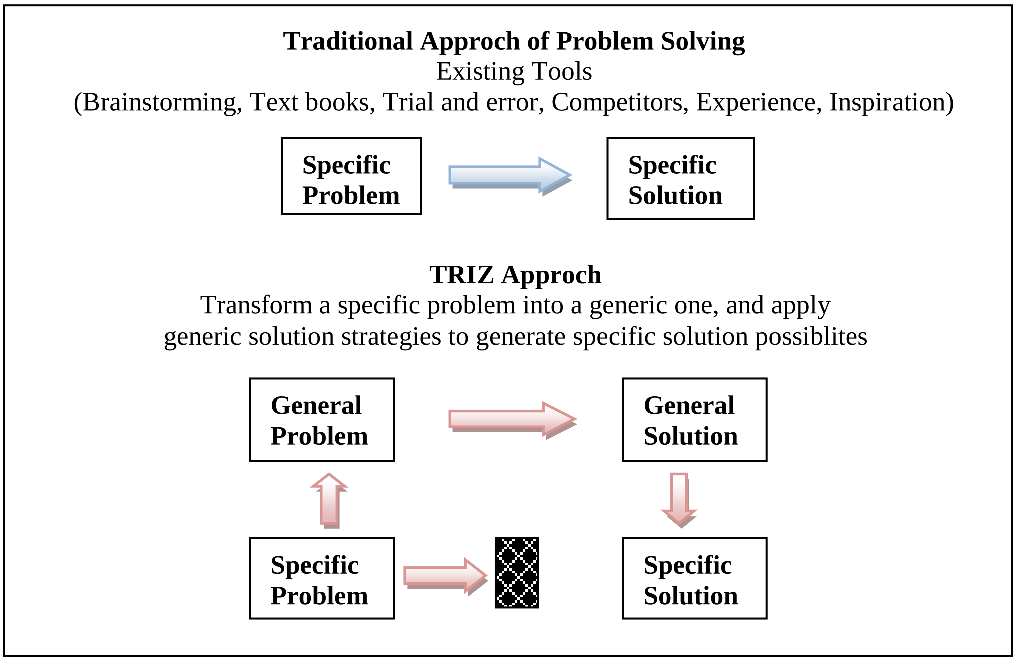

Figure 1: Comparison between traditional and TRIZ approach to innovation
(Source:[8] Frobisher, 2010)

2.1 The Common TRIZ Model and Tools

Various methods and tools are employed in TRIZ innovation technology, which over the years have proved to be successful, including Problem Formulation, Contradiction Matrix, 40 Inventive Principles, Functional Analysis, Separation Principles, Substance Field, Ideal Final Result, Effects, ARIZ, and so on. Users can select appropriate tools to solve their problems depending on the type of problems [5]. The problem definition tools in TRIZ help in the standardization of a specific problem, and reformulate it into a TRIZ general problem. These tools start off with the model of the problem (e.g. Engineering Contradiction, Physical contradiction, Function Model, and Substance-Field Model), based on this general problem (or model of problem). TRIZ provides the tool for resolving this (e.g. Contradiction Matrix, System of Standard Inventive Solutions). The user still has to take the final step of determining the type of specific solution needed based on the suggested TRIZ general solution (e.g. 40 Inventive Principles, 76 Standard Inventive Solutions). This would be the Model of solution, where a specific Inventive Principle or a specific Standard Inventive solution is selected, and a solution is generated for solving the specific problem [6]. Other methods /tools also integrate the Model of the Problem, Tool, and Model of Solution, such as ARIZ (Algorithm of Inventive Problem Solving) It is a complex method having many iterative steps. ARIZ used for the non-standard engineering problems that contain implicit contradictions, and these problems cannot be solved with application of Principles or standards alone. ARIZ has several versions that have been modified and transformed little by little during its history of development [7]. The most important components in TRIZ are depicted in Table 1.

Table 1: The most important components of TRIZ (Source: Pavel Livotov, 2008)

No	TRIZ- Tools, Methods	Field of application
1	40 Inventive Principles for eliminating technical contradictions; system of their application in the form of the Contradictions Table.	Simple to moderately difficult tasks, recommended for newcomers to TRIZ.
2	System of 76 Standards for solving technical problems: 5 classes / 76 standards.	Simple to difficult tasks.
3	Step-by-step techniques or algorithms for inventive problem solving (abbr.: ARIZ). Universal tool for solving all kinds of problems.	Extremely difficult problems, comprehensive search for solutions.
4	Substance-field analysis of technical systems.	Tools for method no. 2 and 3.
5	Separation principles for eliminating physical contradictions.	ARIZ tool (no.3).
6	Methods for analyzing system resources.	Tool for nos. 2 and 3.
7	Database of physical, chemical, geometrical, and other effects and their technical applications.	TRIZ knowledge base; tools for component nos. 1 to 5.
8	Methods to increase creative thinking, to reduce psychological inertia, and to “leave beaten tracks”: operator DTC (dimensions-time-cost), simulation with “Little People,” and so on.	Psychological aids for all TRIZ components.
9	Method of Anticipatory Failure Identification (AFI) technical systems.	Analysis and prediction of possible sources of failures.
10	Patterns of evolution of technical systems (TS).	Prediction for the development of technical systems, creation of patent fences.

3. Case Study

Driving safety has been a major focus of the automotive industry for many years. Car manufacturers have poured millions of dollars into researching safety and regulatory devices and the result has been an astonishing improvement in the safety of even the most inexpensive vehicles. It's easier now than it's ever been to find a car that will let you and your family ride in comfort and safety. Some of the most impressive safety improvements involve braking. The ability to stop a car in a safe manner is crucial in preventing accidents. One of the most successful recent refinements to antilock braking systems has been Electronic Brake Force Distribution, or EBD. EBD is based on the principle that not every wheel needs to put forth the same effort into bringing the car to a stop. In a regular braking system, brake force distribution in passenger cars was controlled by a proportioning control valve that maintained a fixed front/rear brake force distribution under all circumstances. Figure 2 shows the brake force distribution for regular braking system.

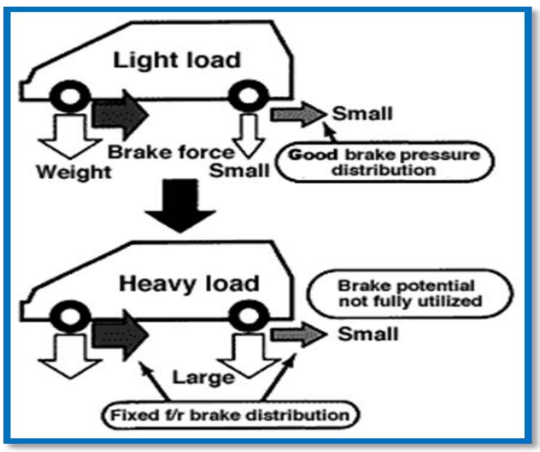

Figure 2: Brake force distribution for regular braking system

When the brake pedal is applied, the brake fluid travels from the master cylinder to the brake cylinders. When the fluid goes inside the brake cylinder, the pressure of the fluid being applied forces the two pistons to push out resulting in the brake shoes or pads being pushed out as shown in Figure 3. This push or pressure is in direct proportion to the push by the pistons, which causes the shoes or pads to rub against the drum or calliper. This reaction creates friction and decreases the turning of the wheels.

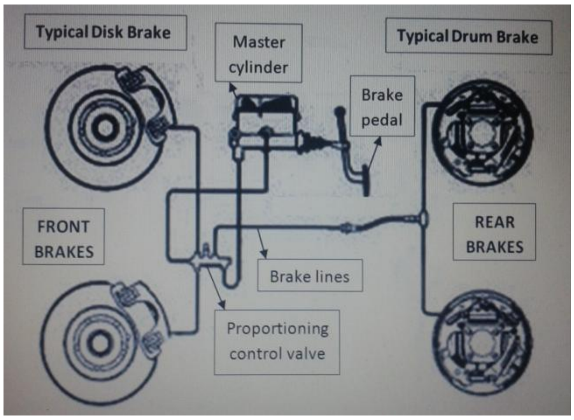

Figure 3: Components of braking system

3.1 Constructing the Contradiction

One of the core parts of the TRIZ tools is the Contradiction Matrix which was formed by 39 Engineering Parameters and the suggestion of 40 Inventive Principles listed in this matrix. It is to say, the contradiction will exist as long as the system to be. Contradiction is defined as an improvement in one characteristic of a system results in the degradation of another characteristic. Traditionally these problems are addressed by compromise, sacrifice or trade-off.

For optimum brake performance, brake force distribution between front and rear wheels should take into consideration both load condition and weight transfer under braking. The improving parameter selected was weight of moving object (Parameter 1) while the worsening parameter was force (Parameter 10). From the intersection of improving and worsening parameters in Contradiction Matrix, statistically significant Principles are mapped out as shown in Table 2.

Table 2: Part of Contradiction Matrix

Improving Parameter	**Worsening Parameter**
	10 Force
1 Weight of moving object	8, 10, 18, 37

From the Contradiction Matrix, the Principles identified were Anti-weight (Principle 8), Preliminary action (Principle 10), Mechanical vibration/oscillation (Principle 18) and Thermal expansion (Principle 37).

Principle 8: Anti-weight

a) To compensate for the weight of an object, merge it with other objects that provide lift
b) To compensate for the weight of an object, make it interact with the environment
➔ Car with aerodynamic shape

Principle 10: Preliminary action

a) Perform the required change of an object before it is needed
➔ Electronic Control Unit (ECU) receives input from the speed sensors, calculates the slip ratio of the wheels, and uses the brake force modulators to apply an appropriate amount of force to keep the slip ratio of each wheel within a reasonable range.
b) Prearrange objects such that they can come into action from the most convenient place and without losing time for their delivery
➔ A speed sensor is placed on each wheel to determine wheel speed.

Principle 18: Mechanical vibration/oscillation

a) Cause an object to oscillate or vibrate
b) Increase its frequency
c) Use an object’s resonant frequency

d) Use piezoelectric vibrators instead of mechanical ones
e) Use combined ultrasonic and electromagnetic field oscillations
➔ There is no innovation under this solution

Principle 37: Thermal expansion
a) Use thermal expansion of materials
b) If thermal expansion is being used, use multiple materials with different coefficients of thermal expansion
➔ There is no innovation under this solution

3.2 Solution

EBD is electronically controlling front/rear brake force distribution according to front/rear weight distribution. This system improves braking stability and performance, particularly under heavy load. EBD is based on the principle that the weight being supported by the wheels of your car is not evenly distributed. Some wheels carry a heavier load than others and will require more brake force in order to bring the car to a stop without it going out of control. Furthermore, the amount of weight being supported by a wheel will shift during the braking process, so the amount of force necessary at each wheel can change rapidly. An EBD system can not only detect how much weight is being supported by each wheel, but change the amount of braking power sent to each wheel on an instant-by-instant basis. Figure 4 shows the brake force distribution for modern braking system with EBD.

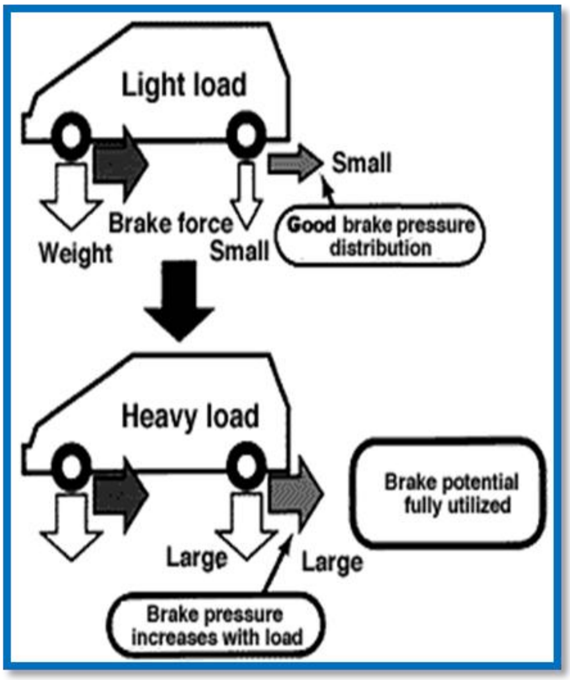

Figure 4: Brake force distribution for modern braking system with EBD

EBD is especially helpful when carrying several passengers and luggage in the back and sudden stop is required. Sensors recognise the extra load on the rear axle, and EBD takes into account the extra weight and applies more braking to the rear wheels. Conversely, with just a driver in the car, EBD applies more braking force to the front wheels and less to the rear wheels as in this case the front wheels will have the most effective stopping power.

4. Conclusion

A new transformation is required to push the automotive industry beyond its current performance through use thinking tools and inventive problem solving methods as a quality improvement methodology in processes, products, and services. In this study, the TRIZ method is applied to solve the problems of a braking system in a passenger car. TRIZ methods like the 39 Engineer Parameters, the 40 Inventive Principles and Contradiction Matrix are applied to approach the final solution.

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