

A Study on the Role of TRIZ in DFSS

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ABSTRACT

The Design For Six Sigma (DFSS) process consists of four phases, identification & definition of opportunity, concept development, design optimization, and design verification. In the phase of concept development, TRIZ (Russian acronym for Theory of Inventive Problem Solving) is useful for creating new ideas from the present ideas, which includes the trimming strategy, the antidote strategy, and the picket fence strategy.

In this paper, systems of a vehicle such as Variable Compression Ratio (VCR) engine, windshield wiper blade, and Continuously Variable Valve Actuation (CVVA) of engine, are selected and new concepts for each system are created by applying the previously mentioned three strategies.

FMEA (Failure Mode and Effects Analysis), the latter part in the phase of concept development in DFSS, is conducted for newly generated concepts of systems that are mentioned above. As a result of FMEA, it is found that the wind lift of the wiper blade can be a serious problem. Therefore, in attempt to fix the wind lift problem of the wiper blade, the optimization process is applied to it in the phase of design optimization. All the factors, including input, output, control factors, and noise factors, which influence the wind lift of the wiper blade, are identified. The activity of optimization process is conducted to obtain the optimized design of wiper blade. In the phase of design verification, the optimized design of the windshield wiper is tested in a real vehicle and it is proved to meet the target value of evaluation criteria for the wind lift. The conclusion is that TRIZ in the second phase of DFSS makes it possible to create new concepts from the present ones, which can be optimized and then later verified to meet the requirements with the follow-up phases of DFSS.

CITATION: Kim, J., Kim, I., Lee, H. and Park, B., "A Study on the Role of TRIZ in DFSS," *SAE Int. J. Passeng. Cars - Mech. Syst.* 5(1):2012, doi:10.4271/2012-01-0068.

INTRODUCTION

As the circumstances of automotive industry change, it is expected to find a way to develop creativity in order to solve engineering problems or to create new ideas. There are activities to develop a new concept in the phase of concept development, the second phase of DFSS. The phase of concept development which provides the greatest opportunity for innovation is the place where the most important decisions are made. It is broadly believed to be the place where 80~90% of the cost and performance are determined. So creating new ideas in the second phase of DFSS is essential to succeed in DFSS projects. In the phase of concept development, there are many ways to create or develop concepts through brainstorming, benchmarking, Pugh method, and etc. Among the several creativity tools, TRIZ provides effective tools for creativity. It helps engineers to overcome the innovation killers such as psychological inertia, limited knowledge, and contradiction. It also helps to solve the problems and create new ideas. In addition, TRIZ provides the effective tools which enable engineers to predict

the future technology and get the new ideas from it. This study shows how TRIZ is used in the second phase of DFSS to create new ideas by improving or modifying the present concepts and ideas. With TRIZ, it is possible to develop the more refined concepts than present ones. The concept produced by conducting TRIZ is in the initial stage and may not satisfy the criteria of performance and reliability due to failure modes. In this case, it is necessary to find the failure mode of the concept which needs to be corrected and improved. Therefore, conducting FMEA on the concept is needed to identify potential failures. It is also needed to conduct the optimization process during the phase of design optimization, in order to fix the failure mode of the concept and hereby optimize the concept. As a result of optimization, the concept gets to reach the ideal function and becomes robust against the noise factors. In the last phase, the phase of design verification, the optimized concept is embodied and then a test is conducted to verify whether the optimized concept satisfies the target value of the related company evaluation criteria. This study presents the role of TRIZ in the second phase of DFSS. It also shows how to connect the

concept coming from TRIZ tool and the follow-up activities to the second phase of DFSS, for example FMEA, optimization process, and verification of results, in order to make the concept robust (less variation) and efficient (high performance) in the development of vehicle.

TRIZ ROADMAP

TRIZ consists of two-step activities, problem identification and problem solving connected to concept creation. Each step includes several detailed tools. TRIZ process and the tools for TRIZ are shown in Figure 1. Each of TRIZ tools has its own characteristics and engineer can apply these tools to their own problem in order to get the solutions and improve their ideas and designs.

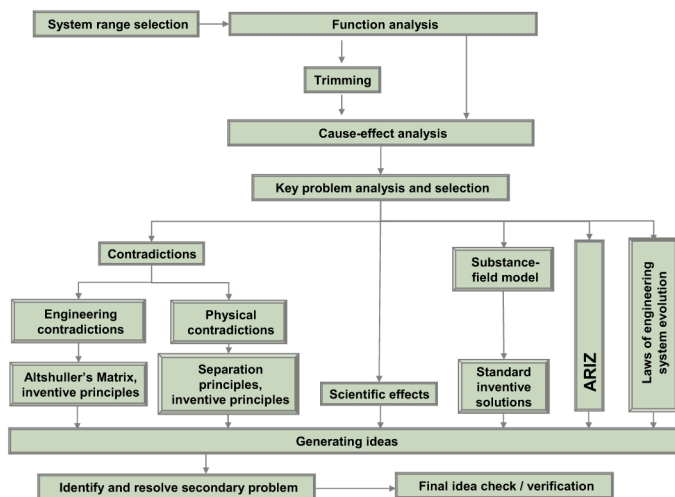


Figure 1. TRIZ Roadmap

The function analysis is a tool for problem identification. It describes functions and their usefulness between components of system and supersystem, and therefore it can identify the key problems which need to be solved. Trimming is a tool which removes certain components of the system and delegates their functions to one of the components in the remained system. The trimming is useful to create new ideas with low cost compared to the present concepts.

The contradictions, scientific effects, substance-field model, ARIZ (Russian acronym of Algorithm for Inventive Problem Solving), and the laws of engineering system evolution are used for problem solving and idea creation. Altshuller's Matrix, inventive principles, and separation principles can be used when an engineering system encounters the situation with contradictions, for example engineering/physical contradictions. An engineering contradiction is a situation where one parameter is improved while another parameter is worsened. Altshuller's Matrix is a problem solving tool and provides certain inventive principles for solving the engineering contradictions. A physical contradiction is a situation in which an engineering system demands contradictory values from the same parameter. A physical contradiction can be solved by using

the separation principles which separate contradictory demands. When the applicable solutions and technology are available in other industries, the scientific effects are very effective. The scientific effects are the problem solving tools based on identifying existing technologies and utilizing them. When both engineering problems and models of solutions are described as the interaction between substances and fields, substance-field model can be used. If a satisfactory solution can't be found by using tools such as contradictions, scientific effects, and substance-field model, it is recommended to use ARIZ. ARIZ transforms an unclear and fuzzy initial engineering situation into a very well defined model of the problem while it expands the resources to help solving the problem. When an engineering system has too many problems and contradictions and thereby it is hard to create a solution, the laws of engineering system evolution enable to bring new concepts of the next or future generation.

DEVELOPMENT OF CONCEPT IN THE SECOND PHASE OF DFSS

There are strategies which enable to create new ideas from the present ones. They also enable to strengthen our own ideas and thereby prevent others from circumventing them.

1. Trimming strategy
2. Antidote strategy
3. Picket fence strategy

TRIMMING STRATEGY

The trimming is to eliminate one or several components of the system while retaining or even improving the functionality of the system. The resulting system will be of higher value compared to the original system because it will have lower cost and will be simpler. So the resulting system becomes the new concept. The sequence of the trimming strategy is as follows. First, the function analysis is conducted on the present concept. Based on the function analysis result, certain components of the present system are eliminated and their functions are carried on by other components of the remained system to create new concept. To demonstrate the effectiveness of trimming strategy, Variable Compression Ratio (VCR) engine and a wiper blade of windshield are selected and new ideas are developed on them as examples.

1. Case study on VCR engine

This strategy is applied to the development of VCR engine to get a new concept compared to the present concept as shown in Figure 2. If the compression ratio of the engine becomes large, then the thermal efficiency increases and thereby fuel economy is improved, but the engine power decreases due to the knocking. So the engine needs to have high compression ratio (high C/R) to get the higher fuel

economy, while it needs to have low compression ratio (low C/R) to get the higher engine power.

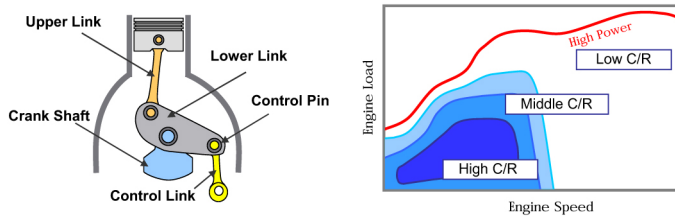


Figure 2. Present VCR Engine

Figure 3 shows the function analysis on the present system and the trimmed system. The component A, B, C, the control link, and the control pin are trimmed as shown in the present system of Figure 3. The function to move the lower link is delegated to the cylinder block as shown in the trimmed system of Figure 3.

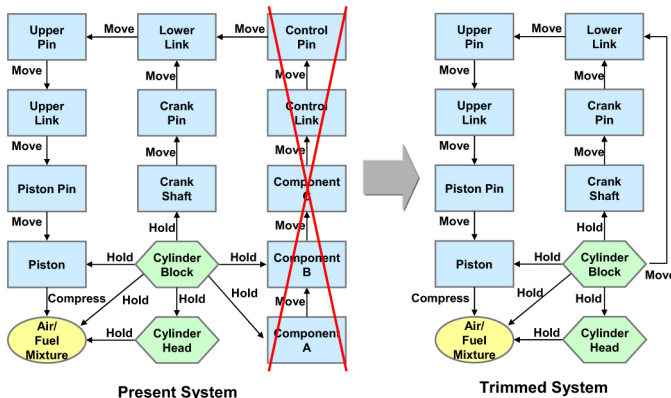


Figure 3. Function Analysis and Trimming in VCR Engine

As a result of trimming, there is a secondary problem that the cylinder block has to move the lower link. This is because it is not known about how to move the lower link with the cylinder block. So the inventive principles are used to solve the secondary problem as shown in Figure 4. The inventive principle no. 14 (curvature; the traveling path for the control pin is curvilinear inside the control slot.) is applied to find the path for the bottom part of lower link. The inventive principle no. 15 (dynamics; the control slot moves up and down under the condition of variable compression ratio.) is used to get the idea about changing the position of the control slot and meeting the target value for both low and high compression ratio. The new idea of the control slot is suggested as shown in Figure 4. By incorporating the control unit which adjusts the position of the control slot, the concept of control slot is completed.

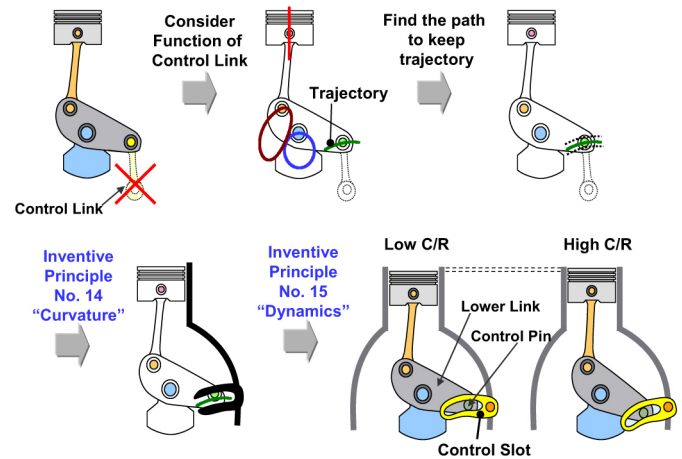


Figure 4. Idea for Secondary Problem Solving

2. Case study on a wiper blade

Another case study for the trimming strategy is a wiper blade on the windshield. Figure 5 shows the present wiper blade which consists of primary/secondary cover, primary/secondary lever, and yoke, etc.

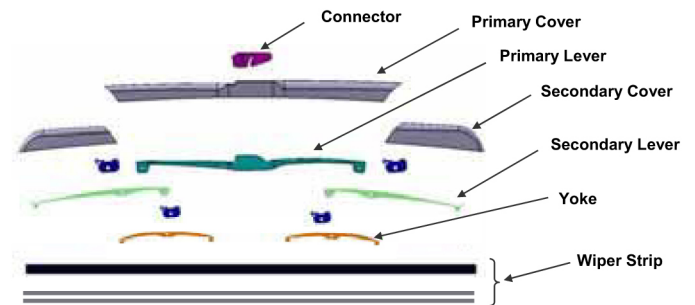


Figure 5. Present Wiper Blade

Figure 6 shows the function analysis on the present system and the trimmed system. The primary lever of the present wiper blade whose function is to move the secondary lever is trimmed and the function to move the secondary lever is delegated to the primary cover.

The new concept is produced as described in the trimmed system of Figure 6. The primary cover of the new concept moves the secondary lever, while it does not move the secondary lever in the present system. Figure 7 shows the new concept of the wiper blade. As a result of trimming, the new concept reduces the number of components compared to the present system and thereby reduces the cost of the system.