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Abstract:

Design for Six Sigma (DFSS) is a systematic process and a disciplined problem prevention approach to achieve business excellence. Robust design is the heart of DFSS. To enable the success of robust parameter design, one should start with good design concept. Axiomatic Design, a fundamental set of principles that determine good design practice, can help to facilitate a project team to accelerate the generation of good design concept. Axiomatic Design holds that uncoupled designs are to be preferred over coupled design. Although uncoupled designs are not always possible, application of axiomatic design principles in DFSS presents an approach to help DFSS team focus on functional requirements to achieve design intents and maximize product reliability. As a result of the application of axiomatic design followed by parameter design, the DFSS team achieved design robustness and reliability. A hydraulic lash adjuster case study will be presented.

Keyword: Design for Six Sigma, robustness, innovation and axiomatic design, parameter design.

1. Introduction to Design for Six Sigma (DFSS)

In order to be successful in today's business, any company needs to strategically plan all development projects with the right level and the right kind of development to achieve maximum efficiency. *It has been estimated that 85 percent of the problems with new products not working as they should, taking too long to bring to market, or costing too much is the result of a poor design process (Ullman, 1997)*. A good design process is supported by a set of efficient methodologies. It has been widely accepted that the early phases of the engineering design process are the most critical to the technical and economical success of a new product. Therefore, the use of an efficient methodology for this crucial stage is most important. DFSS consists of a set of needs-gathering, engineering and statistical methods to be used during product development. Engineering determines the physics and technology to be used to carry out the product's functions. DFSS ensures that those functions meet the customer's need and that the chosen technology will perform those functions in a robust manner throughout the product's life.

To achieve a cultural shift focused on continuous improvement, we must go beyond Six Sigma by leveraging extensive experience in a full suite of performance improvement tools. We need to develop the skills and resources to help us to select and use the most effective tool to address the issues we are facing. Whether those are within the traditional Six Sigma framework or other process improvement methodologies, the details need to be developed to assist us in making the right choice to get the right value.

Often during the implementation of a Six Sigma program a robustness limit is encountered. This limit is due to inherent design issues. To reach a break through result requires a review of some or all of the processes, components or systems and a redress of the deficiencies. This process of redesign is called Design for Six Sigma (DFSS). Improving the robustness of a hydraulic lash adjuster, shown in Figure 1, to the noise factor of oil aeration will be used to demonstrate this process.

The hydraulic lifter provides a hydraulic lash compensation device to automatically eliminate all spaces (lash) between the valve train components of an operating engine. The hydraulic lifter has replaced the mechanical lifter in many automotive engines. A typical lash adjuster overall function diagram is show in Figure 2.

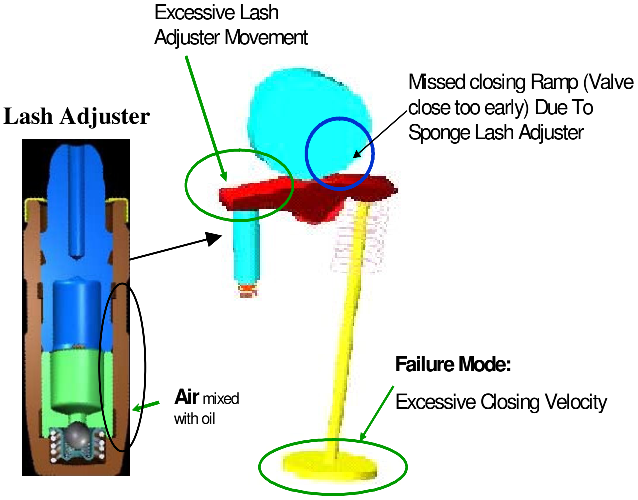

Figure 1: Lash adjuster and valve accuation mechanism

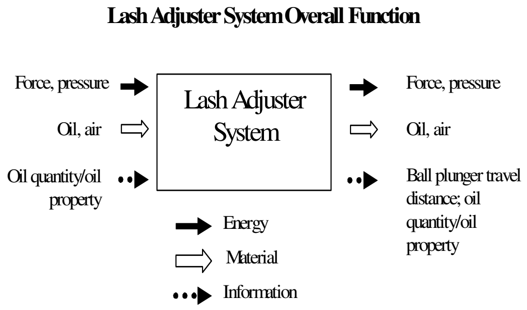

Figure 2

Hydraulic valve lifter operation is based on the incompressibility oil trapped in the high-pressure chamber and the controlled leakage of oil from that chamber. Although the hydraulic lash adjuster offers several specific advantages, it also has some disadvantages. One of the disadvantages is less overall valve train stiffness. If air is captured in the oil (aeration), the bulk modulus of elasticity of the oil is reduced. This further reduces the stiffness of the valve train. The hydraulic lash adjuster is one of the key concerns to cause the valve failures when it cannot maintain sufficient stiffness to perform its intended function. The improvement of hydraulic lash adjuster robustness against aeration in the lubrication system is essential as engine aeration levels increase. Previous attempts to solve valve failures due to this failure mode achieved limited results through continuous quality improvement efforts. These efforts used traditional hardware design of experiments, CAE modeling study and correlation studies. However, such repeated efforts become efforts of cause detection only. No matter how tightly the components were controlled, the performance of the lash adjuster in terms of plunger movements was not acceptable in the presence of high aeration, shown in Figure 3. The ideal performance should be no difference when the hydraulic lash adjuster system is exposed to high levels of oil aeration. To obtain this ideal performance, a breakthrough approach is required.

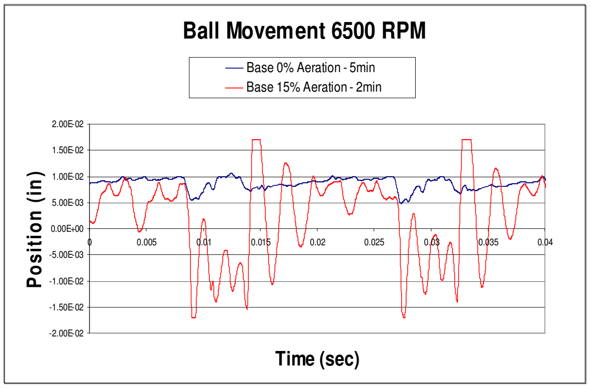

Figure 3

It is therefore a challenge for the team to have a breakthrough approach to improve the robustness of lash adjuster design against aeration.

Instead of constantly debugging products and processes that already exist, a re-examination of the function and design parameters is required. The process best suited to this task is DFSS.

DFSS starts from scratch to design the product or process to be virtually error free. This effectively replaces the usual trial-and-error or built-test-fix style and results in product designs that consistently meet customer requirements. There are several different types of roadmaps or models with different focus on generic technology development or product commercialization such as I^2DOV (Invention, Innovation, Develop, Optimize and Verify); CDOV (Concept, Design, Optimize and Verify); IDDOV (Identify, Define, Develop, Optimize and Verify); DMADV (Define, Measure, Analyze, Design and Verify) and etc.

Table 1 shows the comparison of different DFSS roadmaps.

Table 1: Comparison of Different DFSS Roadmaps

<table>
<tr><td></td><td colspan="4">Roadmaps</td><td colspan="4" rowspan="2">Comments</td></tr>
<tr><td></td><td>Phase 1</td><td>Phase 2</td><td>Phase 3</td><td>Phase4</td></tr>
<tr><td rowspan="5">DFSS
Value Creation & Prevention
Timing: Start early</td><td>1. Invention Innovation</td><td>Develop</td><td>Optimize</td><td>Verify</td><td colspan="4">I^2DOV- Focus on technology development.</td></tr>
<tr><td>2. Concept</td><td>Design</td><td>Optimize</td><td>Verify</td><td colspan="4">CDOV- Focus on product commercialization based on the optimized technology. It is best used with model 1 together.</td></tr>
<tr><td>3. Identify Define</td><td>Develop</td><td>Optimize</td><td>Verify</td><td colspan="4">IDDOV- a combined model in terms of technology development and product commercialization.</td></tr>
<tr><td>4. Define</td><td>Charact-erize</td><td>Optimize</td><td>Verify</td><td colspan="4">DCOV - a combined model in terms of technology development and product commercialization.</td></tr>
<tr><td>5. Define Measure</td><td colspan="2">Analyze
Design</td><td>Verify</td><td colspan="4">DMADV – a model similar to DMAIC with different focus. Measure in DMAIC is to determine current performance and analyze the root causes of the defects and costs. The measure in DMADV is to determine Customer needs and analyze, design the process options to meet the customer needs.</td></tr>
<tr><td>6 Sigma
(DMAIC)
Defect & Cost Reduction</td><td colspan="3">6 Sigma is applied to continuous improvement of existing processes as well as to the design of new process.</td><td>Define</td><td>Measure</td><td>Analyze</td><td>Improve</td><td>Control</td></tr>
</table>

From the Table1, the name of the roadmap or model in DFSS is not important but the contents and tasks needed to be carried out at each phase as defined are.
A typical Ford Motor Company's Design for Six Sigma has four phases –Define, Characterize, Optimize and Verify (DCOV) and can be summarized as follows:

Define – Identify market needs. Define customer requirements and project goal. Identify Critical to Satisfaction (CTS's) and Related Functional Targets.

Characterize - Understand System and Select Concepts. Flow Down to CTS's to lower level (y's) Relate CTS's (y's) to Critical to Quality (CTQ) design parameters (x's).

Optimize - Design for Robust Performance Minimize product process sensitivity to manufacturing & usage conditions.

Verify - Assess integrated system, subsystem, *Performance*, Reliability & Manufacturing. Verification that design performance and ability can meet customer's requirements.

This process, however, does not identify how to develop a design to meet the functional requirements. As a systematic tool, Axiomatic Design, a function focused scientific approach for the synthesis and analysis of product design, developed at MIT by Nam Suh [1], is one of the DFSS tools that can help to ensure that the design specifications, manufacturing capabilities and systems integration are fully aligned with the voice of customers. Axiomatic Design provides a rational structure basis for evaluation of proposed solution alternatives and the subsequent selection of the best alternative. When the limitation of a given design optimization is evidenced, the concept design improvement may have to be considered.

2. Introduction to Axiomatic Design

Axiomatic Design is a principle-based design method focused on the concept of domains that seeks to reduce the complexity of the design process. It accomplishes this by providing a framework of principles that guide the designer or engineer. The primary goal of axiomatic design is to establish a systematic foundation for design activity by two fundamental axioms and a set of implementation methods [1]. The two axioms are:

Axiom 1: **The Independence Axiom**: Maintain the independence of functional requirements.
Axiom 2: **The Information Axiom**: Minimize the information content in design.

In the axiomatic approach, the design world consists of four distinct domains: a *customer* domain with customer attributes (CA:s), a *functional* domain with functional requirements (FR:s), a *physical* domain with design parameters (DP:s) and a *process* domain with process variables (PV:s). The design process involves mapping between these four domains and can be fitted in the four phases of DFSS as shown in Figure 4. A specific design is modeled as a mapping process between a set of functional requirements (FRs) in the functional domain and a set of design parameters (DPs) in the physical domain. This mapping process is represented by the design equation:

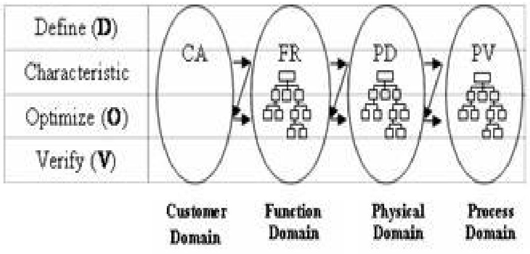

Figure 4

$$\mathbf{FR}=[\mathbf{A}]\ \mathbf{DP} \tag{1}$$

Where

$$Aij=\frac{\partial FR_i}{\partial DP_j} \tag{2}$$

Suh defines an uncouple design as a design whose A matrix can be arranged as a diagonal matrix by an appropriate ordering of the FRs and DPs. He defines a decoupled design as a design whose A matrix can be arranged as a triangular matrix by an appropriate ordering of FRs and DPs. He defines a coupled design as a design whose a matrix cannot be arranged as a triangular or diagonal matrix by an appropriate ordering of the FRs and DPs. The categories of design based on the structure of the design matrix are shown is Figure 5.

$$\begin{pmatrix} X & 0 & 0 \\ 0 & X & 0 \\ 0 & 0 & X \end{pmatrix} \qquad \begin{pmatrix} X & 0 & 0 \\ X & X & 0 \\ X & X & X \end{pmatrix} \qquad \begin{pmatrix} X & X & X \\ X & X & X \\ X & X & X \end{pmatrix}$$

Uncoupled **Decoupled** **Coupled**

Figure 5. Structure of the design matrix

The first axiom advocates that for a good design, the DPs should be chosen so that only one DP satisfies each FR. Thus the number of FRs and DPs is equal. The best design has a strict one-to-one relationship between FRs and DPs. This is known as uncoupled design. If DP influences the FR, this element is non-zero. Otherwise it is zero. The independence axiom is satisfied for uncoupled design matrix [A] having all non-zero elements on its diagonal, indicating that the FRs are completely independent. However, complete uncoupling may not be easy to accomplish in a complex world, where interactions of factors are common. Designs where FRs are satisfied by more than one DP are acceptable, as long as the design matrix [A] is a triangular, that is, the non-zero elements occur in a triangular pattern either above or below the diagonal. This is called decoupled design. A decoupled design also satisfies the independence axiom, provided that the DPs are specified in sequence such that each FR is ultimately controlled by on unique DP. Any other formation of the design matrix that cannot be transformed into triangular one represents a coupled design, indicating the dependence of the FRs. Therefore, the design is unacceptable, according to Axiomatic Design.

The Information Axiom provides a means of evaluating the quality of designs, thus facilitating a selection among available design alternatives. This is accomplished by comparing the information content of the several designs in terms of their respective probabilities of successfully satisfying the FRs.

A primary tenet of axiomatic design theory is the first axiom, stating that independence of functional requirements should be maintained throughout the design process. As the high level requirements are decomposed into greater detail, and information added to the design with the goal of creating a realizable system, the designer creates subsystems that satisfy the first axiom. While higher-level decisions imply an intent that should be maintained as detail is added, this is often not done.

3. Limitations on General Optimization Phase in DFSS and DMAIC

Six Sigma is one of the most innovative and successful methodologies to have been introduced in recent years at an industrial level. The goal of this approach is to increase the efficiency of the company system and to generally reduce the costs involved in the production process. Six Sigma is, therefore, generally used for optimizing processes. After an initial Define phase, Six Sigma can be subdivided into: Measure, Analyze, and Improve & Control. Product optimization can be developed in greater detail by using Design For Six Sigma (DFSS) techniques during the Improve phase. The efforts will be much more effective if DFSS is used in the earlier design stage. These techniques adopt a statistical approach in order to assess which design solutions are best and the system response associated with the solution chosen. However, with an existing design, the success of optimization can only be reached to certain level. The desired success cannot be achieved without changing the concept (structure) of the product or process design. The lash adjuster robustness improvement project is such an example that, with the given design, no matter how the optimization was investigated the goal of a robust design could not be realized. The bottom line is that every attempt reaches the same conclusion about the same significant factors but fail to provide proper improvement direction.

When a company attempts to execute poor design concepts and wrong design decisions made during the design stage, the competitiveness of the company is compromised. Unfortunately, this situation currently exists in many of today's Six Sigma or Design for Six Sigma projects. Decisions made during the design stage of product and process development profoundly affect product quality and productivity [Suh95].

The traditional approaches to design optimization or robust parameter design are limited to optimization of design parameter values and neglect opportunities at concept design. Especially, traditional statistical based problem solving focused on symptoms rather than design intent optimization. Very few efforts are focused on the design functional structure (concept).

There are many grounds for claiming greater power and opportunity for improving robustness at the concept design stage. Figure 6 supports this point using broad empirical evidence from numerous studies.

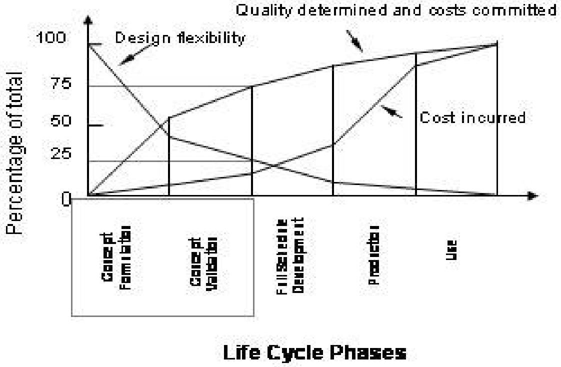

Figure 6: Effect of life cycle phase on design flexibility, total quality and cost determined, and total costs incurred. (Adapted from Nevins and Whitney [NW89])

As seen in Figure 6, by the completion of concept design, approximately 75% of the final quality is determined. Decisions made during concept design have an overwhelming impact on many quality determinants such as number of parts, fabrication methods, allowable manufacturing variations, and yield. Delaying improvements beyond the concept design phase limits the potential for increasing quality.

Figure 6 also shows the greatest deign flexibility coinciding with the greatest number of quality determining decisions. The concept phase is a period of great latitude, design freedom, and many design options. Upon entering the detail design phase, the engineer’s ability to change the design is severely limited by a commitment to specific design features and a greater investment of time and resources. The combination of great design flexibility and great impact on total quality makes concept design the point of greatest opportunity for improvement. Robust parameter design approach to increasing robustness by making improvements in the detail design stage amounts to improving subsequent prototype iterations. Such changes, of course, are much better than no efforts in optimization before the production launch but cannot remedy bad first designs. Robust design must be applied at the concept phase to facilitate good first design. Taguchi does recognize and promote the need of robust design efforts in early design stage such as system design.

Since the attainable level of robustness is very much reliant on the chosen conceptual solution for the technical system. Robust design focusing on parameter optimization can reduce performance variation but only to a limited extent. Figure 7 illustrates how parameter optimization and better concept identification can affect the robustness. Two different conceptual solutions utilizing different solution principles may feature completely different robustness properties. It is very likely that this initial robustness, or conceptual robustness, provides the necessary foundation that makes future optimization by means of designed experiments more rewarding. One concept solution may, for example, be very sensitive to changes in temperature, whereas the other solution shows no signs of such weaknesses. If the future product has to operate in an environment that features temperature variation, the second concept will probably serve better.

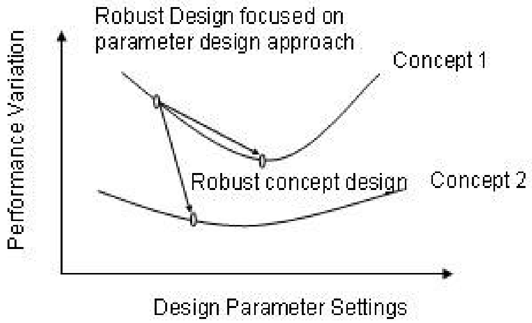

Figure 7: Conceptual robustness and its influence on parameter performance

From the previous discussion, it is obvious that engineering designers need a tool for robust design in the conceptual design phase. The creative process has been described as an ideation process that is highly subjective and dependent upon the specific knowledge of the designer and their ability to integrate this knowledge. Suh proposes a design approach based on the idea that the design process should not remain in the field of experience and artistic skill but should be guided by a formal axiomatic design methodology. Axiomatic design can be used to enhance creativity. It demands the clear formulation of the design objectives through the establishment of functional requirements (FRs) and constraints. It provides the criteria for good and bad design decisions, which help in eliminating bad ideas as early as possible, enabling designers to concentrate on promising ideas. The analytic process is deterministic, based upon basic principles, and serves to evaluate the concepts of the creative process. Suh provides two axioms used in the analytic process for the purpose of distinguishing good designs from bad. Without these axioms, Suh considers design decisions to be made at best on an “ad hoc” or “empirical” basis such as algorithmic design. For example, design for assembly (DFA) and design for manufacturability (DFM) techniques are algorithmic methods.

4. Transfer Function and CTQ (Critical-to-Quality) Selection

The transfer function plays key a role in engineering and is part of Design for Six Sigma strategy. The transfer function is a subsystem-to-system input-output relationship. Transfer functions are set up as equations expressed in Y=f(X). Y relates to output measure. X relates all input variables. Transfer functions are either developed from analytical engineering models or estimated empirically through directed experiments. Transfer functions can be formulated at each level of the system flow-down structure.

As an example, when we discuss about the customer driven six sigma projects, the Kano Model of quality for customer satisfaction is a good high level transfer function. Y, as a system output, can be identified as customer satisfaction (CS). X, as a system inputs, can be expressed in terms of performance quality, basic quality and excitement quality. The format of Y=f(X) may be written as following:

Y_{CS}=f(Performance Quality, Basic Quality, Excitement Quality) (3)

Where, performance quality represents the "spoken", or verbalized, wants from customers. Basic quality represents the requirements that customers will not usually talk about or even think to request (just be there). Excitement quality is "unspoken" and is unexpected by customers. Based on the transfer function, one can identify a specific area as a CTQ for the quality improvement efforts. A simplified lash adjuster Kano Model may be shown in Figure 8.

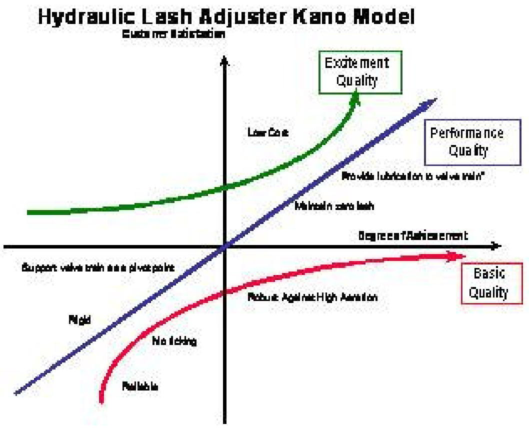

Figure 8

Based on the Kano Model, the basic quality of robust against high aeration in lash adjuster is a CTQ and absolute essential for the key function of lash adjuster design. The high level basic transfer function (BF) may be expressed as following:

$\mathbf{Y}_{BF}$=f(Reliable, No Noise/Ticking) (4)

DFSS commences from flow-down design specifications, parameters, and variables based on the Voice of Customer (VOC). As a systemic tool, axiomatic design can guide project teams through the process. In axiomatic design, synthesized solutions that satisfy the highest-level FRs are created through a decomposition process that requires zigzagging between the functional domain and the physical domain as shown in figure 9.

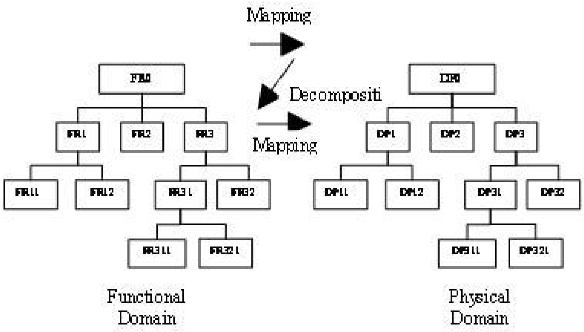

Figure 9: FR – DP Zigzag Mapping

It decomposes a top-level FR into leaf level FRs, which are not decomposable any further. Designer creates leaf level DPs in his braor extracts those from his knowledge base to satisfy the corresponding FRs. Once leaf level DPs are found, they must be integrated to create the whole design artifact, which is then checked to determine if they work well and satisfy FRs based on two design axioms.

One effective way of promoting innovation and problem solving is to require designers define the functional requirements first without to any regard to how such products can be made. When FRs are unambiguously stated, designers can evaluate their proposed design. Once FRs are defined, they should develop basic ideas for products based on basic principles, making sure that the chosen DPs satisfy the FRs and the independence Axiom. A quality product satisfies all the FRs. Without carefully stated FRs at all levels of decomposition, the quality of products, a minimum requirement, can be very difficult to measure. Even benchmarking cannot be done without clearly stated FRs. Benchmarking existing product against competitors can only deal with DPs rather than FRs, unless FRs is stated. While Six Sigma focuses on improving existing designs, DFSS concentrates its efforts on creating new and better ones. The identification of a CTQ is a key step to have higher success rate for the Six Sigma project. Fundamental to the success of a Six Sigma Project is to estimate the CTQ improvement margins and the extent of the resultant cost saving. By calculating the Information Content of the principal FRs present in the system it is possible to ascertain from the AD schematization which is the most critical characteristic of the process or product (CTQ). The Information Content measures the probability for every FR to be satisfied, so it can be used to evaluate to what extent the main FRs are able to meet the specifications. This characteristic can also be expressed in terms of the process sigma number, thereby making it possible to compare the two measurements. In this way the most critical FRs, which will become the CTQ characteristics of a Six Sigma Project, can be identified. In the case study of lash adjuster, a more specific and measurable transfer function can be expressed as following:

$Y_{Stiffness}$=f (Valve Closing Velocity, Plunger Movement) (5)

5. Applying Axiomatic Design Framework To Develop Creative Design Solutions

After utilizing all available tools in Six Sigma and Design for Six Sigma, it was determined that the limitation of optimized results and the improvement efforts may not be effective unless the concept design is challenged. Lash adjuster quality concern related problems generated in the functional and physical domain were discovered during the detail review. From an axiomatic design perspective, this analysis corresponds to Axiom 1. The idea is to review and redefine the function requirements based on the design intents and the quality history and to uncouple the concept as much as possible, to avoid unnecessary interactions. The lash adjuster design functional requirements (FR) may be stated as follows:

FR1=Maintain zero valve train clearance
FR2=Support Rocker Arm as A pivot
FR3=Supply oil for lubrication
FR4=De-aerate

The FR-DP hierarchies are produced by the zigzagging decomposition process. FRs are defined as "what we want to achieve" in functional domain and DPs are defined as "how we want to achieve it" in physical domain. The decomposition process conceptually divides a big, complex problem into solvable small pieces and finds design solution for the divided small problems. It produces language descriptions of decomposed FRs and DPs. A DP is a description of a proposed solution to satisfy the corresponding FR, and play a role as a key design variable as a part of the whole design solution. The term description is used to explicitly represent the meaning of FRs and DPs. The existing lash adjuster design parameters are mapped as followings:

DP1=Hydraulic check valve system
DP2=Mechanical system
DP3=Oil lubrication system

A mapped functional domain to design parameter domain of the lash adjuster design is shown in Figure 10.

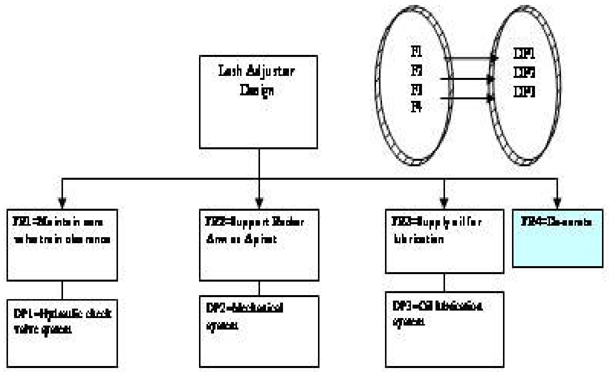

Figure 10: Lash Adjuster Function Mapping

Based on the facts of FR-DP mapping, it is obvious that the number of design parameter is less than the number of functional requirements. The design structure is coupled due to the missing number of design parameter. This process identified a feature not considered by the original design. Identifying the required function enable the development of a new design parameter to satisfy the de-aerate functional requirement, shown in Figure 11.

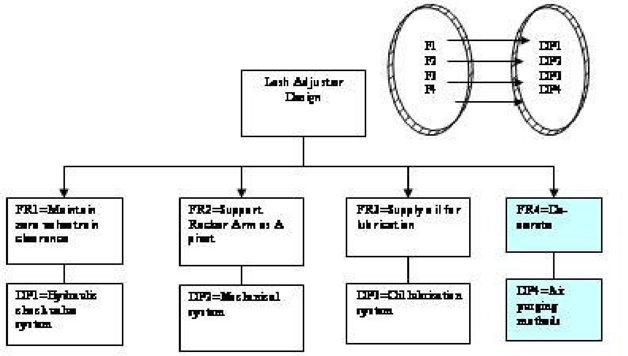

Figure 11 : Design Parameter Improvement

With the neutral designed DP – air purging method, creative thinking was motivated and encouraged to come up with several new designs. Two of the new designs were filed for patent applications. Since the alternative concept designs are available and being considered, the Pugh Concept Selection process provides an objective way of thoroughly evaluating these design concepts alternatives. In addition, it often helps to synthesize the "best of all worlds," that is, come up with a new design that is better than the initial alternatives. The Pugh technique compares alternative design concepts to a datum (or base) concept, typically the current design, using a complete set of evaluation criteria. The objective of the Pugh technique is not necessarily to pick winners or losers but to gain insight and ideas from the many possible alternative concepts along with the effort of taking the subjectivity and biases out of the analysis. With defined lash adjuster design selection criteria, a lash adjuster Puge Concept selection table is shown in table 2.

- Verify that manufacturing process is able to produce the product to its design specifications. Based on the selected concept, a test plan is developed to ensure the CTQ meets the target with minimized variations around the target.

For the case study:

CTQ = Ball plunger movement robust to oil aeration

Table 2 **Lash Adjuster Air Purging Design Concept**

Criteria	Current Design	Flow Through 1	GG Method	Slot Method	Ford Air Bleed
High Pressure Chamber Size		S	S	S	S
Pressure		-	--	S	S
New Feature 1	Datum	+	+	S	+
New Feature 2		S	S	+	S
No Excessive Oil Flow		---	S	S	S
Design Complexity		- -	-	-	-
New Feature 3		++	S	+	++
Cost Impact		+	S	-	-
Time to Purge air from empty lash adjuster		-	-	+	S
Less Morning Sickness (Cold start/noise)		-	+	S	S
Note: **S=Same** **Plus (+)=better** **Minus (-)=worse**		**New Design 1**	**New Design 2**	**New Design 3**	**New Design 4**

6. Verify the Selected Alternative

The fundamental questions which need to be addressed are:

- Are we building or improving the product right?
- Can we validate the design in the user conditions?

Verify phase is an important step in DFSS process. DFSS Verify phase involves three tasks:

- Verify appropriate product design (functional testing) against consumer-driven requirements.
- Demonstrate an acceptable reliability level.

The performance of the new designed lash adjuster is more robust against the aeration, as demonstrated in Figure 12.

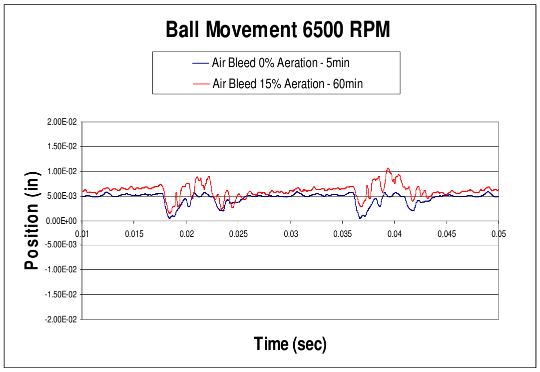

Figure 12 New Design Ball Plunger Movements (More Robust Against Oil Aeration)

7. Discussion and Conclusion

The best performance of designing and launching products under the influence of DFSS comes from using the right tools at the right time from the start to finish during the product development cycle. The advantages of Design for Six Sigma using Axiomatic Design has been discussed and demonstrated in this paper. Improving design robustness is much better to start from concept design. The incorporation of the functional aspects of the DFSS process in a systematic way based on Axiomatic Design can help to facilitate a project team to accelerate the generation of good design concept. A better DFSS process with Axiomatic Deign can facilitate higher value-producing innovations to market in shorter time frames and commercialize them more quickly to meet better-targeted market needs.

Designs that violate the design Axioms may not be optimized effectively. Instead of using Six Sigma DMAIC roadmap, one should use DFSS when:

- A product or process is not in existence at company and one needs to be developed.
- The existing product or process exists and has been optimized (using either DMAIC or not) and still doesn't meet the level of customer specification or six sigma level.

Design for Six Sigma using axiomatic design can enable us to design robust products/processes through:

- Robust Conceptual Design
- Robust Parameter Design
  - Robust Parameter Design through CAE model
  - Robust Parameter Design through hardware experiments
- Tolerance Design

In DFSS, it is important to develop transfer function and identify vital few Critical to Quality characteristics (CTQ). A DFSS project starts with defining CTQ and ends with validating CTQ based on the customer requirements. Applying the axiomatic design framework enables the DFSS team to focus on the functional requirements and enhances creative thinking. This process results in better solutions for robustness and reliability.

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