Design for Six Sigma with integrated approach for New Product Development

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Abstract

This article explains the breakthrough innovation of PON and RES non-marking anti-static tires, using the strong process development principle of DFSS. In this DFSS implementation, two approaches IDOV and DMADV were used for both Product and Process development. Optimize and Validate steps of IDOV approach were integrated to the DMADV approach during process design and development. Optimize and Validate phases were functioning simultaneously during DMADV implementation.

Introduction to Design for Six Sigma (DFSS)

Design for Six Sigma (DFSS) was introduced as a Product Development approach that was additionally included to the traditional DMAIC Lean Six Sigma Problem solving approach. DMAIC Lean Six Sigma usually focuses on continuous improvement projects in manufacturing and service industries. DFSS is focused on expectation of customer needs and systematic application of scientific and statistical methods. DFSS acronym, unlike DMAIC, doesn't represent any standard approach. Therefore, many have adopted methods such as IDOV, DMADV, IIDOV etc. Even though the abbreviations are different, all methods are aimed towards a common goal, which is to create a data driven product development culture and to produce new products. Camso decided to launch PON 775, the non-marking anti-static off the road solid tire through Design for Six sigma (DFSS), which is a product development approach and a part of Six Sigma Problem Solving methodology.

An Overview of Camso & its Material Handling Products

Camso is present in more than 100 countries for the purpose of getting closer to customers and it contains its own foot print in 20 countries. It serves major 4 sectors such as Material Handling, Construction, Agriculture and Power sports. Material handling sector is one of the major business sectors. As per the current scenario in market positions, Camso is having a growth trend in the world OEM (Original Equipment Manufacturer) market whereas competitors like Continental, Trelleborg and other Chinese brands are having growth trends in the After Sales Market. Material handling business unit mainly produces tires for off-Road vehicles such as forklifts, trailers, mining and road construction equipment etc. Among Material Handling segment vehicles, Fork lift occupies the highest share in both OEM and After Sales Markets. SWOT analysis for Material Handling (MH) products was performed and key elements under each category are highlighted in the below Table 1:

Strengths	Weaknesses
Workforce with great Technical expertise (Product Development & Engineering) High Manufacturing flexibility High Market share in OEM market Continuous improvement culture	Less new product launches in the market Customers are not given awareness of quality and safety of the products. Not dominating after Sales Market
Opportunities	**Threats**
Potential growth in OEM business Possibility to adopt modern technology and cost reduction	Increasing product cost High Market competitiveness

Table 1: SWOT Analysis for MH Products (Compiled by the author 2019)

Product development through IDOV approach

Product development through IDOV approach is explained in the below context.

1. Identification (I)

The project was initiated by Product line team of Camso in order to eliminate static buildup of fork lifts that are used for indoor applications. The methodology of Design for Six Sigma was used from Design Stage of this project. The major decision makers of this project decided to use DFSS principles to transfer customer expectation into new product.

There are two major methods to conduct new product and process development in DFSS. Those are IDOV and DMADV. IDOV abbreviation consists Identify, Design, Optimize and Validate. DMADV abbreviation refers to Define, Measure, Analyze, Design and Verify. IDOV mechanism was used to design the product and DMADV concept was used to design process.

For many years Material Handling industry had been facing a problem, which was building-up of Static Electricity in their Non-Marking (NM) Tires. Non-Marking (NM) tires are not conductive. Static Electricity generated is stored rather than dissipated. This situation occurred mostly in high intensity indoor applications. This problem was observed in United States and European region which has got low relative humidity. Condition of dry atmosphere results in huge risk of static electricity buildup. As we know, the electricity generated is stored in the truck and driveline. Upon contact, the shock can be up to 50000 volts. Static electricity creates a spark that can cause severe fire accidents in the presence of any combustible material in the premises. The electricity that was generated caused electrocution or injury to the operators and also caused damages to the properties. Operators' stress increased due to the fear of electrocution and caused low productivity rates. Static electricity buildup also claimed issues related to electrical circuit damage and elevator outage problems at customers' locations.

Camso was asked to investigate overheating and blowout issues of 22x9x16 SM Non- Marking drive tires on new Toyota 8000lb. Among the world Forklift manufacturers, Toyota is one of the leading manufacturer with Non-marking tires. Toyota found a solution with competitor's tire which consisted of fully conductive Tread compound in their tires. Competitor's tires were able to handle the intensity which lapsed, but they were not able to provide longer tire life. Customer's requirement was heat resistant, long lasting and non-marking press-on anti-static solution.

In another occasion representatives from Camso visited Georgia-Pacific, one of the World's leading manufacturers of Tissue, Paper and Packaging materials. They were using standard Fork lifts of brands like Toyota, Nissan, Hyster, etc. The team visited the division which had all Hyster forklifts. These machines were 5000 lb and 12000 lb running with all NM tires. The main problem identified at this facility was the build-up of Static Electricity. A fire accident occurred at their premises due to leakage of propane. When the operator tried to reach the valve to shut it off, build-up of static electricity between the operator and the Fork ignited the propane.

Resolving the safety issue of Static Electricity build-up was a major challenge faced by CAMSO, being a leader in Material Handling tires. Camso determined to find a feasible solution, as they are the pioneers in providing the right product for the Off-the-Road applications. Camso always believes there is a better way in everything they do. Camso started listening to its customers. Customers were more than willing to test tires and actively participated in product development.

Camso recognizes five strategies as their pillars of strength. They are, being the leader of worldwide off-the-Road tire business, one product cycle ahead of competition, Operating Excellence and best location, gaining best reputation and working with great people and teams. In order to resolve the issue in previous paragraphs, CAMSO decided to adapt its "One cycle ahead" strategy, which focuses on adapting to customer needs and developing and providing products at the lowest cost of ownership. CAMSO also decided to invest in the Product Development Team for development of the anti-static product compound.

Below illustrated is the Market trend of Toyota Forklift business and Camso's OEM and After Sales Market (After Sales Forklift tire business). According to the Fig 1.2, it is clearly visible that Toyota is having inclined market trend in their Fork lift operations, while After Sales Forklift tire business of CAMSO has a slightly increasing market trend, which is higher than the OEM market. Camso decided to sustain the After Sales trend in future and also to increase market share of OEM business, as that is a more reliable and reputed business sector. Therefore, to match with Toyota's inclined trend, they had to capture major share of Toyota's Fork lift tire business. Camso believed "One Product cycle ahead" Strategy would change the flat trend into inclined trend similar to Toyota. Also, to capture the market it was necessary to sell the new products with minimum margin at a competitive price.

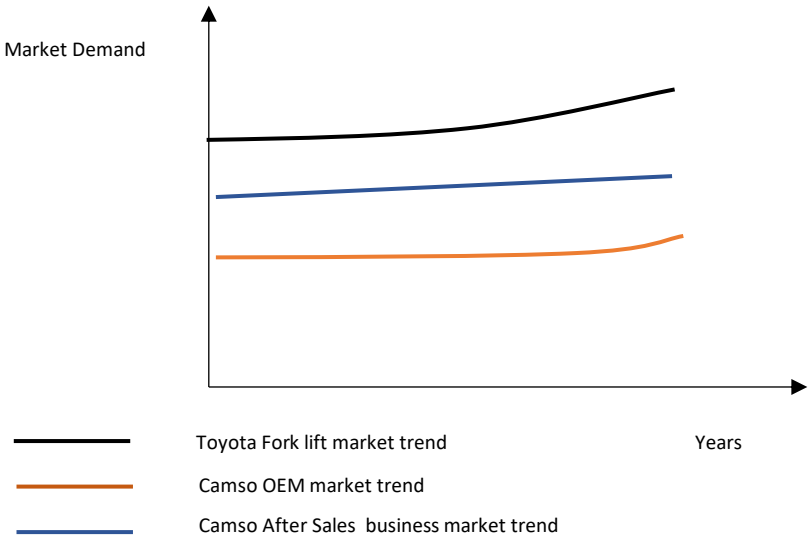

Fig 1.2 (Compiled by the author 2019)

CAMSO introduced an exceptional Product, the Solideal PON 775 NMAS. It provided 63% better resistance to heat build-up and 33% greater energy efficiency compared to the previous generation. Solideal PON 775 NMAS proved that it is the best performer and differentiated from competitors with the best performance of heat resistance, energy efficiency and life span. Since 2018, CAMSO has been supplying its patented non-marking

anti-static technology to material handling fleets. PON 775 is cured with a cylindrical piece of highly conductive black rubber connected all the way from steel wheel to the tread face. As indicated in Fig 1.3, the black dot on the face of the tire is the indication of anti-static tire. This black dot continuously grounds the electricity generated upon contacting with the floor.

Fig 1.3: Anti-Static Tire

Camso's technology is better than the others in the industry. Camso uses rubber, which is resistance to cutting and tearing without compromising life and thermal capabilities. There were many extensive research and validations performed before launching this Product to the Market. A development team with representatives from Product development, Industrial Engineering, Central Engineering and Production embarked on a plan to develop DFSS for Camso. The team adopted the four-phase process (IDOV). The IDOV framework was aligned with CAMSO's existing product development system. Main project was divided into sub projects and growth of sub projects were monitored by Vice President, Material Handling through various periodical reports.

2.0 Product Design and Development (D)

Quality Function Deployment process (QFD) is the process that defines customer expectation and it converts customer expectation into technical specifications. Following are the customer expectation gathered the QFD:

- Tires that provide a solution to Static build-up
- Tire design should improve fuel efficiency of Forklift
- More compatibility for driver
- Long lifetime
- Low cost
- Ability to use for long time period without stopping the Forklift

The product development concepts that are generated at the initial stage of this projects are:

- Converting existing non-conductive tread compound into a conductive compound
- Introducing another mechanism that dissipates accumulated chargers.

  Design Failure Mode and Effect Analysis (DFMEA) is an effective tool which can be used to evaluate this kind of product development ideas. The cross functional team includes following members to conduct the DFMEA using customer requirements gathered from quality function deployment (QFD):

  - Compound development specialists
  - Tool development specialists
  - Process development specialists
  - One of process specialists from manufacturing site
  - Rubber technologists

  Above cross functional team has conducted DFMEA based on their expertise knowledge and identified major constrains of both the options

2.1 Selection of Design Concept based on DFMEA

The DFMEA process generated risk priority numbers (RPN) for each causes of failure modes. DFMEA process is completely based on product performance. Customer or Voice of customer expectation should be converted into technical terms before conducting the DFMEA process. Based on the customer requirements, major product performances which were targeted in this DFMEA are electrical conductivity of tire, heat build-up, rolling resistance, wear resistance and cushioning effect. Therefore, what product development team has focused when conducting DFMEA process are:

- Electricity conductivity (Resistance below 50 Ohm)
- Low heat build-up
- Low rolling resistance
- High cushioning effect

Major causes of failure modes of introducing new conductive tread compound is shown in table 2:

Failure Mode	Causes of failure mode
High resistance to dissipate chargers	Low electricity conductivity of tread compound
Tire fails during running	High heat build-up of new conductive tread compound
High fuel consumption	High rolling resistance

Table 2: Major Failure modes and causes of failure modes of introducing conductive compound

Appearance of the tread compound may not be same as usual compound, because of the conductive feature. Since the conductive compound development is a new task and it takes long time period to complete the project.

Major causes of failure modes of introducing new mechanism to dissipate accumulated chargers is shown in table 3:

Failure Mode	Causes of failure mode
Lack of operator comfortability	No feature to give cushioning effect
High resistance to dissipate chargers	The given mechanism is not sustainable

Table 3: Major Failure modes and causes of introducing new mechanism

This mechanism needs more process improvements to build green tire without affecting the final product quality. Since the conductive path preparation through the tread compound is highly dependent on manufacturing process, process capability is the key component in this option.

Based on the RPN values of DFMEA, it was decided to prepare conductive path through tread compound in order to dissipate accumulated chargers. The major factors influenced to select this option are:

- High electricity conductivity of final product
- Low heat build-up and low rolling resistance of final product
- Final cost of the product
- Time duration comparison with project tasks
  After finalizing the exact product development concept, the Prototype was finalized after ensuring meeting customer expectation.

Optimize and Validate steps of IDOV approach were integrated to the DMADV approach during process design and development.

3. Process Design and Development

DMADV is the concept that we used to design new process to realize the product development concept designed from technical expertise team.

3.1 Define stage of process development (D)

The key players of process development stage are Process Engineering specialist, Quality Specialists, Design Engineering members, Costing Specialists and Production Specialists. In Define stage, the product specification should be clarified from the Product Development team before moving to further steps.

DOE (Design of experiment) is a more effective method that can be used to measure effectiveness of few process concepts and select the most suitable process concept to be implemented. Following are the major concepts that were used to collect inputs to prepare DOE:

- Brainstorming
  A brainstorming session was conducted to collect ideas from Skilled Operators, Group Team Leaders, Team Leaders and Engineers.

- Individual comments from technical members
  Individual comments of technical members who conduct machine modification and maintenance were gathered.

3.1.1 Design and conduct the DOE

The DOE was designed by Process Development Specialists, Quality Specialists, Engineering Specialists and Industrial Engineering specialists based on the data gathered from brainstorming and individual comments gathering process. The DOE included four concepts (A, B, C, D) of processes and the concepts were conducted after preparing

required tools and machineries. Based on the outcome of four concepts, all the processes were evaluated using following criteria (under section 3.3) to select the most suitable process.

3.2 Measure stage (M)

The effectiveness of each mechanism of DOE can be evaluated using PFMEA (process failure mode and effect analysis). PFMEA is a well-structured process that can identify process failure modes and causes of all the failure modes. Based on the RPN (Risk Priority Number) of all the causes, it is possible to select the mechanism having low process risk. Other major factors that affected quality, productivity and cost of product were:

- Operator safety
  Based on the safety risk assessments of each process mechanism, best process mechanism can be selected considering number of low risk components that belong to each process. Based on the level of risks, it is easy to identify possible improvements that are required to improve operator safety.

- RPN values of process failure modes of each process
  PFMEA generates RPN values for each causes of failure modes. During PFMEA process, it is possible to identify all the failure modes and all the causes of failure modes. Number of causes that are having high RPN values were calculated for each mechanism.

- Final product quality
- The time taken for additional process steps
- Financial requirements to implement new tools and equipment
- Additional man power requirement
- Product cost comparison based on raw material, energy and manpower utilization
- Operator dependency

3.3 Analysis Stage (A)

The best method can be selected using above factors that were discussed in measure stage.

Following is the criteria to select the best mechanism,
1-Positive, 0-Neutral, -1-Negative

	A	B	C	D
Operator safety	0	0	1	1
RPN values of process failure modes of each processes	0	-1	-1	1
Final product quality	1	1	1	1
Time taken for additional process steps	1	0	-1	0
Financial requirements to implement new tools and equipment	-1	-1	1	0
Additional man power requirement	0	-1	0	-1
Product cost comparison based raw material, energy and manpower utilization	1	0	0	0
Operator dependency	1	-1	0	-1
total	3	-3	1	1

Based on the facts and figures of all four methods analysis, positive, negative and neutral scores were allocated. When considering the four process mechanisms, the best method was method A. Even though method A has neutral feasibility to safety and negative feasibility to financial requirement to introduce new tools, it is more feasible when compared with other mechanism. Therefore, method B, C and D can be neglected from this selection process.

3.4 Design Stage (D)

Design stage of this project included following steps:

- Designing new tools and equipment that are required for the new process
  During this stage, project team designed a customized machine and new tools
- Reviewing FMEA to identify any hidden risks
- Conducting qualification run to measure effectiveness of the newly designed process
  After the qualification run, there were minor adjustments to complete. Employee training awareness was completed using both theoretical and practical approaches.

3.5 Verify (V)

Verifying stage was the pilot production stage of this project. After completing the pilot run, a mechanism was implemented to audit the process and review PFMEA after each audit. The project was successfully completed after showing the process capability and new product implementation was completed after this milestone.

The new antistatic PON product family was introduced to market after completing the product and process design part in a successful manner. Resilient non-marking tires are popular in Europe region. Similar to PON NM tires, Static electric build-up in Resilient NM tire was experienced by European companies. They also requested a solution for static build up. Since the production process for PON 775 NMAS was well established, resilient antistatic product was easily implemented using the same process without any modification. The strong process development principle of DFSS helped to make an industry breakthrough in PON and RES non-marking anti-static tires.

In this DFSS implemented, two approaches IDOV and DMADV were used for both Product and Process development. Optimize and Validate steps of IDOV approach were integrated to the DMADV approach during process design and development. Optimize and Validate phases were functioning simultaneously during DMADV implementation.

4. Conclusion

Product and Process development through DFSS

In the below displayed flow (refer Figure 4.1), it is briefly explained how IDOV and DMADV approaches were adopted to implement DFSS methodology in new Product and Process development process:

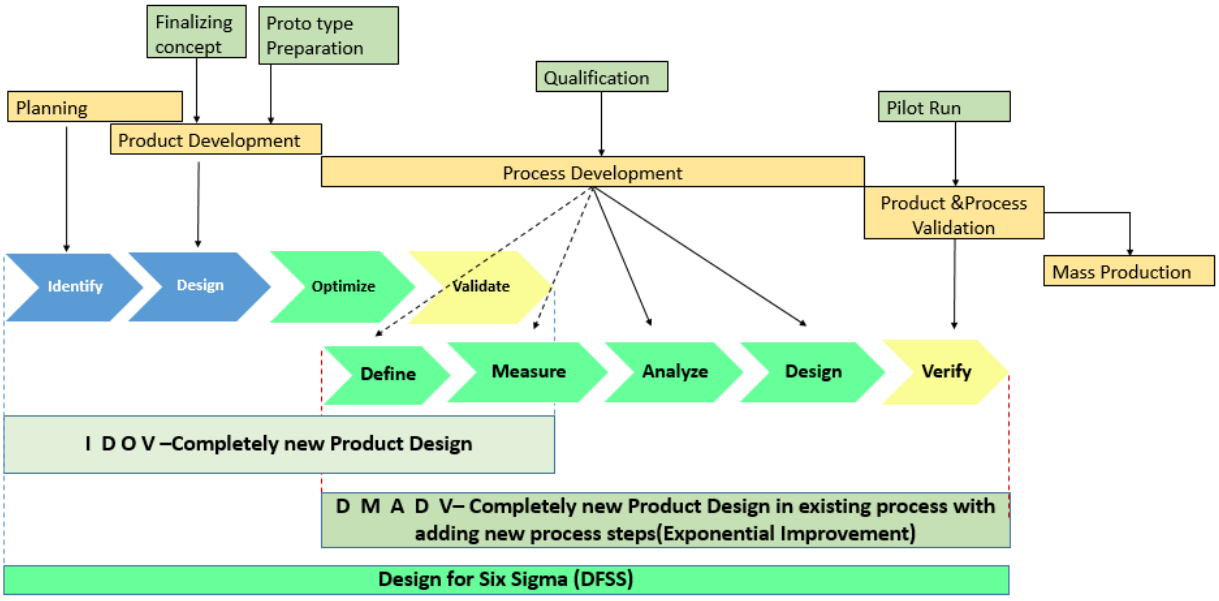

Fig 4.1 The DFSS Process becomes integrated part of the Product Development

As shown in Figure 4.1, with this above illustrated methodology, it is possible to use DFSS for any new product launched to the market.

To succeed in DFSS in future projects, it is necessary to appoint a Master Black belt (MBB) as Head of the department responsible for the Product and process industrialization. The Product PON775 is manufactured at Ekala Tire Division (ETD) plant where more than 1000 employees work. As per the ISO 13053 :2011, required number of Lean Six Sigma trained professionals in the plant are shown in the below Table 5:

Role	Number	Currently allocated / Expected to allocate
Deployment Manager	1	Plant Director
Project Sponsor	1	Vice President, Material Handling
Master Black Belt	1 per 5 black belts	Industrial Engineering Senior Manager (MBB)
Black Belts	1 per 5 Green Belts	Production Managers (BB) QA Managers
Green Belts	1 per 30 employees	Process Engineers, Industrial Engineers and QA Engineers, Shift Mangers
Yellow Belts	800 Employees	All employees

Table 5: Required number of Lean Six Sigma trained professionals in the plant as per the ISO 13053:2011

Camso ETD plant will be working on these training programs for the next 3 years to sustain the Lean Six Sigma culture and also to implement New Product and Process Development through DMAIC and DFSS methodology. It will be a huge opportunity for the plant management, because ETD is the largest manufacturing plant in the world which manufactures material handling tires. It will benefit them to expand their demand by launching new products to the Material handling segment to achieve competitive excellence. According to the Vice President - Material Handling (Camso), “To innovate is to turn an idea into a solution that adds a value from a customer’s perspective. It’s the ability to go one step further to outperform in products and service, with imagination and perseverance.”

References and Bibliography

1. Product launches of Camso https://camso.co/en/material-handling/products
2. Nathan R, S. (2004). Design for Six sigma at Ford. *Six Sigma Forum Magazine*, (NOVEMBER 2004 I 15).
3. PON 775 NMAS: Fixing the safety hazards of static electricity https://www.youtube.com/watch?time_continue=23&v=dpS6US734Ow
4. RES Xtreme NMAS: The ultimate anti-static resilient hero https://www.youtube.com/watch?v=UG3E_y-PW7g