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PRODUCT LIFE CYCLE & QUALITY MANAGEMENT CONSULTING

DESIGN FOR SIX SIGMA AND PRODUCT DEVELOPMENT IN THE PLASTICS INDUSTRY

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Abstract

Developing a product that meets the customer's requirements requires a collaborative effort from marketing, technology, manufacturing and other functions across the organization. Customer's requirements should be translated to specific product properties and specifications. The designed product must be robust during manufacturing and should be shipped to the customer on time and with the right quality. This paper describes the value of critical parameter management using Design for Six Sigma rigor with a case study.

Background

In today's competitive, global environment, new products and innovation are critical to a company's growth and sustainability. Many companies today focus only on cost reduction. Generating revenue via new, differentiated products that lead to organic growth has now become a major focus of many companies. Product development must be done within a long-term strategic context that identifies unmet customer or market needs, emerging market trends, environmental, regulatory and compliance rulings and trends, customer value and financial considerations. This up-front effort will ensure speed to market, early revenues, and negligible or low costs at launch (*Figure 1*). Most companies spend little time in determining the exact customer and market needs up front, and end up spending large sums on money in rectifying the ills of their efforts thus realizing lower profits.

Many companies perceive the development and launching of new products as a significant risk due to uncertainties of success after potentially large investments. In addition, the product development process is not well understood by most firms. Finding, developing, and exploiting new product growth can help corporations deliver sustained customer value with innovative products in existing, growing or emerging markets. It also allows corporations to be flexible, and target desired customers and markets, while enhancing customer satisfaction and maintaining a competitive advantage.

The overall goal is to deliver sustained customer value along with sustained business profitability. Customer and market needs can run the gamut from competitive pricing, superior product performance, on-time delivery, quality service, significant productivity, to ease of use. In attempting to deliver a complex combination of these requirements, a company must also realize significant revenue and healthy profits.

In order to accomplish this, appropriate processes must be in place that aid innovation, and speedy product development from idea to sales – i.e. from customer needs to customer fulfillment.

About Winovia

Winovia® LLC, a consulting company that provides customized, sustainable solutions, strategies and training in new product development and quality management processes and high performance materials. Winovia employs the Six Sigma and Design for Six Sigma philosophy with the goal of strategic market penetration, improving product and process quality and increasing revenues and profits for its clients.

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- Strategic Technology Roadmapping

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Several studies[1-3] have been conducted the last 50 years on companies that are successful in bringing new products and value to customers while sustaining profitability. These companies have the following common characteristics:

- Management commitment, buy-in, support and involvement.
- A quality, structured, flexible, product development process as a business process and *not* for technology and engineering alone.
- Cross-functional development teams working together from concept to commercialization. • Clearly defined product needs – up-front.
- Use of clear metrics, relevant data and data driven decisions.
- Information access and transparency.
- Regular organization-wide pipeline and portfolio reviews, management and strategy.

Over 70% of Fortune 500 companies have some sort of a formalized product development process. The most commonly used process is the Stage Gate® process first introduced by Dr. Robert Cooper in 1988[4]. Several companies have used a modified version of this process. The product development process should be across the business enterprise, where all functions involved are part of a dedicated, cross-functional team. Collaboration, communication and concurrent activities will better ensure success and reduce product development cycle times.

Design for Six Sigma

Design for Six Sigma (DfSS) is a business management, product development process that uses metrics, data, statistics, team dynamics, and project management tools[5,6]. It can be incorporated into an organization's existing product development process and should involve taking products all the way from concept to commercialization.

DfSS is not just about designing a capable product. The goal of Design for Six Sigma is that the new product should have robust (six sigma) performance:

- At the customer, consumer, end-user
- During launch
- During production, and,
- By design

All of the above must be considered when designing and developing a new product.

The DfSS process also is:

- **A portfolio management tool** - It allows an organization to assess their product portfolio and formulate their strategy.
- **A risk management tool** – It facilitates the risk assessment at the end of each phase and enables judicial decisions, avoiding customer issues and unforeseeable costs.
- **A communication tool** – Standardized processes and templates facilitate communication between teams, the business and the customers.
- **A project management tool** – The structured product development process provides a clear understanding of deliverables on product requirements, timelines and budgets during the product development cycle.

The basic concept of DfSS is to clearly understand the customer's requirements and translate them to the critical to quality (CTQ) characteristics of the product (*Figure 2*). Understanding the fundamentals of the product will provide unforeseen flexibility and speed in developing new products. Toyota, known for its high quality and innovative products understands the fundamental capabilities of all the major components (or *critical parameters*) and subassemblies that it uses to build an automobile. The company uses this intellectual power to improve, innovate and develop new models and high quality products at speeds unsurpassed in the global automotive industry. Similarly, plastics compounders can construct raw material and processing databases and design spaces that can provide potent knowledge and information of an organization's core capabilities for new product development.

This article will describe the development of a compounded plastic resin for a molder, looking at how a high quality, cost competitive product was developed on time by focusing on critical parameters that correlated with the customers needs.

Case Study

The Application

The new application was a thin walled part for an electronic assembly. No existing products in the market place met the needs for this new application. *Figure 3* details the requirements for the application. In essence a high flowing material with excellent ductility at a reasonable cost was needed. The challenge was to develop a product with these two contradicting requirements, i.e., when the melt flow increases, the ductility typically decreases. The new product also had to be developed within a period of 6 months.

The formulation and development

Based on the customer requirements, the Quality Function Deployment (QFD) tool was used to drill down to critical property requirements for the products (*Figure 3*). In addition to these properties other requirements of the material included continuous use temperatures, long term ageing requirements and colorability.

To improve the efficiency and speed of the development cycle, both screening design of experiments and optimization design of experiments were conducted.

Screening design of experiments helped identify the key formulation components. These components were chosen from:

1. Semi-crystalline resin: Nylon 6, nylon 66, PET, PBT. (These resins were chosen based on overall needs and cost).
2. Impact modifiers: ABS, MBS, Surlyn, SEBS, MAgSEBS, PE, MAgPE, ethylene acrylate
3. Nucleating agents: Talc, sodium stearate, zinc stearate.

Results from the screening experiments indicated that PBT, MBS and talc were the critical components for the An optimization design of experiments provided the final formulation which was:

PBT 87.2%
MBS 12.0%
Talc 0.4%
Antioxidant 0.2%
Release agent 0.2%

A co-rotating, non-intermeshing, twin screw extruder was used for compounding. Processing conditions of 255°C for the temperature and 100 seconds for the residence time were established. Model equations generated from the design of experiments included both formulation and processing conditions. They are given below:

Melt Viscosity (poise) = -1980 + 135.2* PBT + 128*MBS-110*PBT Moisture -23.5*Temperature - 15.5*Residence Time

(R-Sq Adj. = 95.4%)

MV value by design = 2410 poise

Notched Izod Impact (ft. lbs./in) = -10.2 + 0.03* PBT + 4.5* MBS – 0.013*Temperature – 0.1*Residence Time

(R-Sq. Adj. = 89.8%)

NI value based on design = 5.1 ft. lbs/in.

An example of a design score card is given in *Figure 4*. This scorecard evaluates how the sensitivities of the critical formulation components and processing conditions influence the melt viscosity of the compounded product. The design scorecard enables manufacturing to understand what the control parameters and their tolerances should be during production. It also gives purchasing the critical specifications needed for the raw materials.

The production

The formulated product was then run on a production line, controlling and measuring the following:

- Incoming PBT viscosity
- Incoming PBT moisture content
- Incoming MBS rubber content
- Extrusion temperature
- Residence time (rpm)
- MBS feeder control
- Compounded product melt viscosity
- Compounded product notched izod impact strength

A capability scorecard (*Figure 5*) uses the data gathered during production to identify low performing components and the overall capability of the product. Components with low capability must be improved to ensure a high quality product. In this case the residence time (screw rpm) and the incoming PBT quality (viscosity) consistency was improved.

The commercialization

The commercialized product delivered over 99.9% yield at the customer with C_{pk} of over 1.75 (5.2 sigma capability). Molding conditions once set at the customer never had to be tweaked, as they received a consistent product (lot to lot) over time, translating to increased sales and productivity gains. Supply chain requirements were put in place to ensure on-time delivery of quality product. This product was delivered to the customers at the sales price requested and in less than 6 months from the initial customer request. The company made a healthy profit margin on this product.

Conclusion

Using a structured process to gain insight to the customer's needs and translate them to tangible, critical to quality product specifications, significantly reduces cycle time and ensures a higher probability of success. Using metrics, data and rigor one gains fundamental knowledge about the critical parameters of the product. This shared knowledge is the instrumental in producing and selling a high quality, consistent, cost competitive and profitable product. Design for Six Sigma is a powerful methodology that can be incorporated into an organization's existing product development process to provide its customers with sustained value while generating growth, revenue and healthy profits for itself.

References

1. Donovan G. Evans, Hugh R. MacKenzie, Christian Przirembel *Twenty Elements of a Product Realization Process*, National Design and Engineering Conference, 1996

2. Richard Osborne, *New Product Development – Lesser Royals* Industry Week 65(3):251-258, April 2002

3. Robert G. Cooper *The new product process: A decision guide for managers* Journal of Marketing Management 3(3): 238-255, (1988)

4. Robert G. Cooper, *Winning at New Products*, 3rd Edition, Basic Books, 2001

5. C.M. Creveling, J.L. Slutsky, D. Antis Jr. *Design for Six Sigma in Technology and Product Development* Prentice Hall, New Jersey, 2003

6. Geoff Tenant *Design for Six Sigma Launching New Products and Services Without Failure* Gower, England, 2002

Figure 1 – Cost and Revenue Advantages in up-front efforts in product development

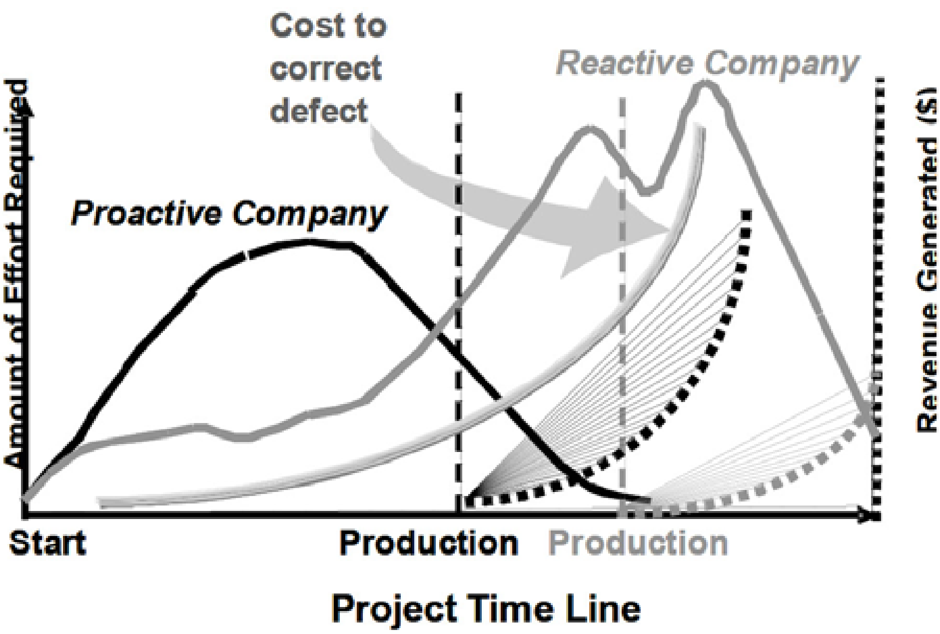

Figure 2 – Six Sigma capability from components to customer performance

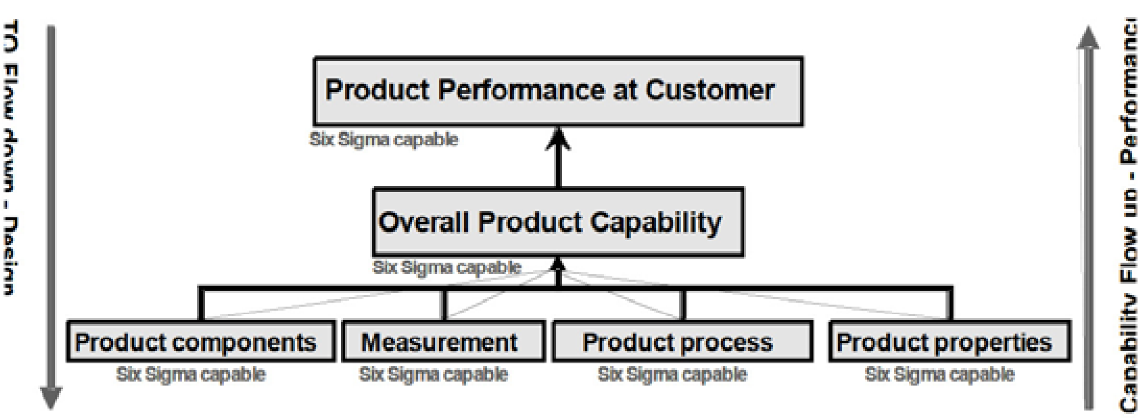

Figure 3 – Critical Parameter Drilldown form Customer Requirements using a QFD

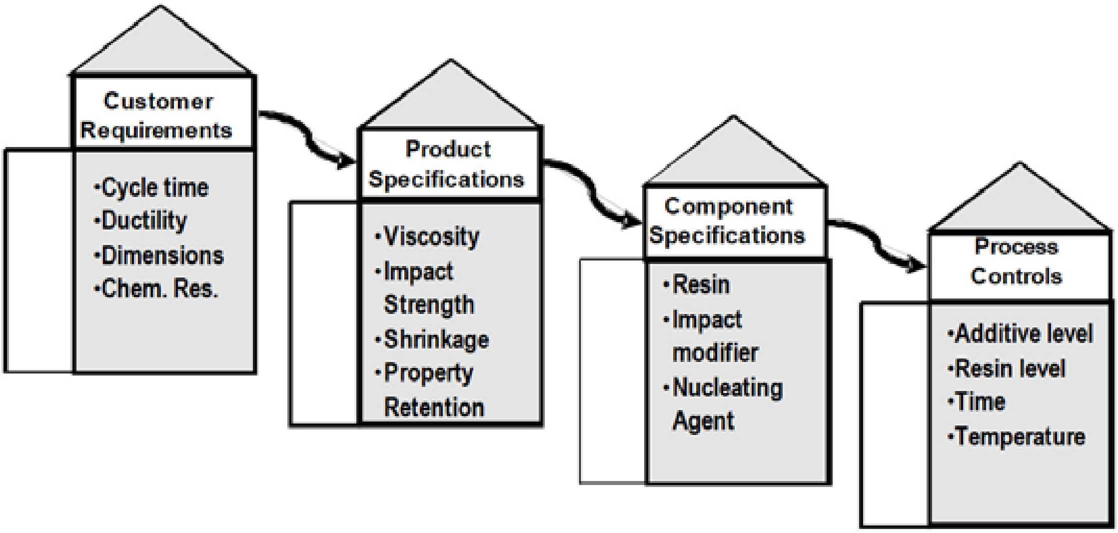

Figure 4 – Design Scorecard for Melt Viscosity Capability by Design

Component	Units	Lower Spec Limit	Upper Spec Limit	Mean	Standard Deviation	Sigma Capability	C_{pk}
PBT	%	86	88	87.2	0.33	2.39	0.80
MBS	%	11	13	12	0.33	2.78	0.93
PBT Moisture	%	0	0.02	0.01	0.00	2.78	0.93
Temperature	°C	252	258	255	1.00	2.78	0.93
Residence Time	secs	95	105	100	1.67	2.78	0.93
Melt Viscosity	poise	2200	2600	2410	36.143	5.24	1.75
Transfer Function:	Response = - 1980 + 135.2 * PBT + 12 * MBS - 110 * PBT Moisture - 23.5 * Temperature - 15.5 * Residence Time						

Figure 5 – Product Capability Scorecard for raw materials, processing conditions and product properties

Parameter	Units	Lower Spec Limit	Upper Spec Limit	Mean	Standard Deviation	Sigma Capability	C_{pk}	
PBT MV	%	1900	2100	2010	15.3	5.85	1.95	Materials
MBS Rubber	%	50	60	55	0.65	7.41	2.47	
PBT Moisture	%	0	0.02	0.011	0.0015	5.96	1.99	
Overall Materials Capability						5.96	1.99	
Parameter	Units	Lower Spec Limit	Upper Spec Limit	Mean	Standard Deviation	Sigma Capability	C_{pk}	
Temperature	C	250	260	255.5	0.73	6.12	2.04	Process
RPM		900	1100	1010	19.8	4.54	1.51	
MBS Feeder Control	%	11	13	12.2	0.14	5.69	1.90	
Overall Process Capability						4.77	1.59	
Parameter	Units	Lower Spec Limit	Upper Spec Limit	Mean	Standard Deviation	Sigma Capability	C_{pk}	
Viscosity	poise	2200	2600	2457	31.1	4.59	1.53	Performance
Notched Izod Impact	ft. lbs./ in	2		4.11	0.3	6.92	2.31	
Overall Performance Capability						4.74	1.58	
Overall Product Capability						**4.85**	**1.62**	**Overall**