Product Specification Management (PSM): Enabling Manufacturing Quality

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Introduction

Achieving superior product quality is both a top goal and a top challenge of product manufacturers. Product Lifecycle Management (PLM) is redefining the use of information throughout the product lifecycle and specifically, as discussed here, in the manufacturing phase of the product's lifecycle.

Product quality is more than a product being manufactured to defined specifications. Product quality is ultimately driven by perceived value by the product user. Linking that perceived value to the right requirements, specifications, and user performance will determine whether a product truly is a quality product.

The four phases of the product lifecycle are create, build, support, and dispose. The task necessary to ns.

"As-built" product information is the creation of a virtual counterpart to the physical product as it is manufactured. "As-builts" have information about what specific parts the product has ("Bill of Material") and the processes that created it ("Bill of Process"). Additionally, measurement and other monitoring information as the product goes through the steps in the manufacturing process should also be captured.

This measurement and other monitoring information (the as-built specifications) are compared to the as-designed specifications. While this PSM information is used to drive decisions on the acceptance of the manufactured product[i], these as-built specifications are also used to create the informational counterpart to the physically manufactured product, the virtual product.

PSM information creates the virtual products that consist of all the necessary information about the physical products that are being manufactured. As described below, this virtual information can be used in place of being in possession of the physical product itself.

Prior to PLM, inspection information about the product that was collected during the manufacturing process was used to make pass/fail decisions about the product at a certain manufacturing operation. Statistical Process Control (SPC) was a more sophisticated method that used intervals of inspection data to catch

produce quality in the create phase is to develop a set of product specifications that meet the user's requirements. In the product build or manufacturing phase, the task is to produce a product that conforms to these specifications. Under the PLM framework, Product Specification Management (PSM) is the approach that creates a comprehensive informational view of the as-built manufactured product in relation to these specificati o

problems at specific manufacturing operations before they reached the "fail" stage.

In too many companies, the inspection data was not even used for these purposes. Inspection data was collected and never acted on. It was hand recorded on pieces of paper and filed away only to serve as unhappy evidence in a product liability lawsuit that indeed there was a problem.

Using a PLM approach, the opportunity exists to not only create the physical product, but to capture the information about that physical product and create a corresponding virtual product. That virtual product can be used to reduce the waste of physical resources both within the manufacturing cycle and throughout the other phases of the product lifecycle.

This whitepaper will explore this new model of product information and describe its potential for greatly improving the efficiency of product creation and manufacture.

Defining PLM

Product Lifecycle Management (PLM) is an integrated, information-driven approach comprised of people, processes/practices, and technology to all aspects of a product's life, from its design through manufacture, deployment and maintenance—culminating in the product's removal from service and final disposal. By trading product information for wasted time, energy, and material across the entire organization and into the supply chain, PLM drives the next generation of lean thinking.

Grieves, M. (2006). Product Lifecycle Management: Driving the Next Generation of Lean Thinking. New York, McGraw-Hill.

Information Mirroring Model and Virtual Products[ii]

PLM depends on the conceptual idea of real and virtual products. Before the advent of computer systems that could handle the massive amounts of information about a product, the only practical way to have information about a product was to physically possess the product itself.

If a quality inspector wanted to check the dimensions on a batch of components, then the components were physically shipped to the inspector. (In many firms, inspection of the received product at the firm's site is still the primary quality control practice.) While blueprints were available on the "as-designed" component or product, "as-built" information on each instance of the component or product that was built from that design rarely, if ever, existed.

All products start out as virtual products. That is ideas and information about what the physical product should be. These virtual products are then realized in physical form through the manufacturing process. The manufacturing of products can be divided into three phases: making the first one, ramp-up, and making the rest.

"Making the first one" entailed getting a physical product that embodied the ideas of what the virtual product was required to accomplish. Ramp-up and production ("making the rest") relied on the premise that these products would be close enough to the first one so as to be functionally and physically equivalent. The accuracy of that premise varies widely even today, which is why expensive quality audit inspection processes are required of the actual product instances themselves.

Progressive manufacturing processes now capture data about the product as it is being manufactured so as to create not only integrated product and process traceability, but a virtual product model as the physical product is being built. As inspection processes become more technologically sophisticated and automated, the ability to create robust virtual representations of individual physical components and products becomes not only possible but necessary.

These virtual representations form one of the components of the PLM Information Mirroring Model (Figure 1) and are a main element to allow Product Specification Management (PSM) to exist and perform a critical role in enabling quality as part of PLM.

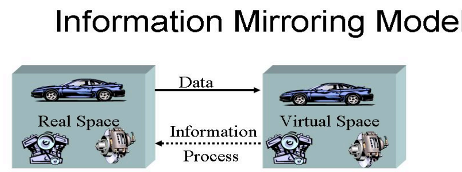

Figure 1

Product Specification Management (PSM)

Product Specification Management (PSM) is the key to product quality in the manufacturing phase of the product lifecycle. Once a virtual product has been created that is validated as meeting the requirements that the product should possess, it is defined as the "controlling" or master virtual product. The controlling virtual product is the virtual product that is to serve as the template for all the physical products to be manufactured. The next step is to then build a physical product that meets the specifications of this controlling virtual product.

To create this physical product, a Bill of Process (BofP) is developed. A BofP is a step-by-step list of operations that is to be performed on material in order to create a physical product that meets or "mirrors" the specifications of the virtual product.

The physical product is of a different nature from the virtual product in that it exists in many instances, each with its own characteristics, slightly different from the others and from the controlling virtual product. Each of these product instances will be produced at a particular point in time and in a particular geographical location.

As the physical product is manufactured, information about each instance – its shape, its dimensions, the torque applied to its fasteners, etc – is also created. The task of PSM is to capture this information for each product instance individually and for the collection of instances across time and geographical extension.

As the Information Mirroring Model in Figure 1 illustrates, this information about the physical product should be used to create a virtual product that represents the manufactured product, both from the point of view of each individual instance and from that of the collection of instances.

This "as-built" virtual product can then be compared from various useful perspectives against the controlling "as-designed" virtual product to determine if it meets the necessary specifications.

This is Product Specification Management (PSM). The difference between PSM and spot quality control inspections or even statistical process control is that PSM involves creating a comprehensive view of the manufactured product across time and geography and is not simply a data point or a small set of points viewed from a narrow perspective.

In various ways, traditional inspection is limited in that it makes use of relatively small sets of data points in isolation from other data points that might be useful if viewed from an integrated perspective. For instance, under traditional inspection, only a very small set of features on a given product instance may be inspected or used. Or, only a very small sample size of the collection of instances may be inspected. Or only a very small portion of the manufacturing process may be inspected for the purposes of a particular functional area of an organization (fabrication, assembly, final inspection, etc.).

The key innovation of PSM is that it consolidates information from all the available data points for use in any way necessary within an organization – across time, geography, and stages of the manufacturing process.

While PSM information can still be used to pass or fail an individual instance of the product or to determine the trend line using SPC techniques, the information becomes part of an "as-built" virtual product that can be used within the manufacturing phase and also in other phases of the product's lifecycle.

The Value of Virtual Products

There are a myriad number of uses that can be made of the virtual product created through PSM. In the manufacturing or build phase, the "as-built" virtual product is immediately available and can be transmitted to customers and other parties in the supply chain who need the information about the product to assure themselves that the product is actually being created to the required specifications.

Unlike the physical product itself, the virtual product can be sent over large geographic areas instantaneously and can be sent to multiple locations simultaneously. As described elsewhere[iii], the new slogan of "transmit us the virtual product and we will then tell you whether or not to ship the physical product" may define a new paradigm in purchasing and manufacturing.

One automotive manufacturer has created a collaborative virtual space with its suppliers where the inspection of component parts at the supplier and later at the OEM is correlated down to the inspection point – though each may use different inspection methods and devices. The introduction of this collaborative model contributed to an 85% reduction in build issues in the subsequent model year as reported by the OEM.

In the create phase, the as-built virtual product can be used to validate the design of new, similar products. The data collected on actual results compared against specifications is invaluable in assessing manufacturing validity of new designs. By providing a feedback loop, the engineering / manufacturing divide can be bridged, reducing the slow iterative process of trial-and-error typically performed by manufacturing companies.[iv]

For instance, while a specification and its associated tolerances may be manufacturable for the beginning of a production run, it may be that tool and die wear over a much larger run does not allow for those specifications to be met. Having the sequence of virtual products allows designers to understand either the requirement for different specifications or understand when new tool and/or die replacement is required.

At another automotive manufacturer, historical process capability information contained in the as-built virtual product of current and previous product models is being captured in the early design of new product models. This is in the form of dimensional tolerances that can realistically be expected to hold using similar manufacturing methods. In the absence of PSM technology, defining the proper tolerances in design for manufacturability (DfM) is a notoriously uncertain and difficult exercise, where the risk is that improperly assigned tolerances will lead to costly rework in design and tooling.

In the support phase, the issue of product liability often hinges on proving whether or not the individual product was manufactured to the required specifications. Without the ability to present data about the manufacture of a specific product, companies are at the mercy of plaintiff attorneys who raise doubt about the manufacturing process by asking "Isn't it possible that the bolts holding my client's seat were not tightened properly? (Grieves, "Multiplying MES Value") Having the as-built virtual product, especially after the physical product may have been destroyed in an accident, gives the manufacturer protection against such an accusation.

Already, the US government has legislated detailed traceability at the level of individual product instances as a requirement on the F-35 JSF aircraft program, necessitating the implementation of PSM technology by the prime defense contractor and its suppliers.

Components of PSM

In order to create the virtual product of an individual physical product, there are three main components that need to exist. These components are: physical measuring tools, a data collection and organizing system, and a virtual product representation. These components are in varying states of progression. However, they are rapidly evolving.

Taking the virtual product representation first (the right side of Figure 1), this component already exists in a fairly mature form. Product specifications in the form of CAD definitions fully and with great accuracy define the dimensions of the virtual product. Defining other characteristics such as force application (e.g. bolt torque force) and material specification other than dimensional (e.g. tensile strength, plasticity, etc.) are at varying stages of being integrated into virtual product representations.

On the left side of Figure 1 or the physical or real product, there is numerous hardware measuring systems that are being introduced on to the factory floor. Coordinate Measuring Machines (CMM's), laser measuring systems, and white light systems are just some of the hardware tools that are measuring the physical product in order to provide the data necessary to create a virtual product.

The line in Figure 1 that connects the physical data collection to the virtual representation is a very critical aspect of this model. While the hardware measurement tools collect data on specific areas of interest, this data needs to be collected and organized in a comprehensive fashion. This PSM software needs to collect the input from disparate physical data collection tools in different formats and organize that data into a virtual product.

Without PSM, the physical data collection is simply individual data points that have limited usefulness. PSM software is rapidly evolving to meet the requirement of creating virtual products from the physical products.

Conclusion

Product Specification Management (PSM) is a critical concept under PLM in realizing superior product quality in the manufacturing or build phase of a product lifecycle. As products are manufactured, the information about the products, both dimensional and other key characteristics, are captured and used to create a virtual product that informationally mirrors the physical product.

These virtual products provide value in a number of ways. While the virtual products can be used to make decisions about product pass/fail, the virtual products can be transmitted immediately in lieu of shipping the physical product. Virtual products can also be used in new design validation and to improve overall manufacturing quality.

The components required are software systems for dimensional and other product characteristics, equipment to measure and capture the information of the manufactured products, and software necessary to collect and organize this captured information into virtual product form.

These components are evolving quite rapidly. Companies wishing to take their quality efforts to the levels necessary for the increasingly competitive marketplace need to understand, develop, and implement PSM.

About Dr. Michael Grieves

Dr. Michael Grieves is a world renowned authority on Product Lifecycle Management (PLM). Dr. Grieves has written and lectured extensively on the topic and is a frequent keynote speaker on PLM. Dr. Grieves' works include the seminal work on PLM, Product Lifecycle Management: Driving the Next Generation of Lean Thinking (McGraw-Hill, 2006).

Dr. Grieves splits his time between the business world and the academic community. Dr. Grieves has over 30 years of executive experience in public and private companies. He is a Research Professor at Oakland University, which houses his PLM Institute. Dr. Grieves is a Co-Director of the Purdue University PLM Center of Excellence. Dr. Grieves has been the Director of Industry Research at the University of Arizona MIS Department and a Visiting Professor at Purdue University College of Technology. Dr. Grieves serves as the Chairman Emeritus of the Board of Visitors at Oakland University's School of Business Administration. Dr. Grieves co-founded the PLM Development Consortium at the University of Michigan, College of Engineering.

Dr. Grieves has a B.S.C.E. from the College of Engineering, Michigan State University, an MBA from Oakland University and a doctorate from the Weatherhead School of Management at Case Western Reserve University.

[i] This has historically been referred to as Quality Control. It is more accurately Specification Control. For a PLM view of quality, see Dr. Michael Grieves, *Product Lifecycle Quality (PLQ): A Framework within Product Lifecycle Management (PLM) for Achieving Product Quality*, in the Manufacturing Journal of Manufacturing Technology and Management (forthcoming).

[ii] This section has been slightly modified from the original version in *MES: Achieving Real Quality through Virtual Products*.

[iii] See Dr. Michael Grieves, *MES: Achieving Real Quality through Virtual Products*.

[iv] See Dr. Michael Grieves, *Multiplying MES Value With PLM Integration.*