Applying Modern Manufacturing Processes to Engineering Prototypes

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INTRODUCTION

Why Study Prototype Processes?

Today's global economy has reached a scale that no one could have imagined possible just a few decades ago. Perhaps the most obvious result of this world-scale economy has been the expanded customer base for consumer goods and services. However, a broader consumer base has brought with it more stringent customer requirements for goods and services. A customer's ability to obtain goods and services from any number of competing companies both at home and abroad make it imperative that suppliers of these products perform flawlessly the first time and every time. Consumer expectations for quality have assumed all-time highs. The current paradigm insists that world-class quality be no more expensive today than mediocre quality was in days past. Given this environment, manufacturers attempting to peddle goods viewed by consumers as having sub-standard quality or a price tag that is too high are likely to find those goods sitting in their inventories while competitors gain market share. Disney's Michael Eisner has been quoted as saying what brings managers down isn't "the lack of understanding some arithmetic table, not the lack of understanding what the information highway is, but the lack of understanding why somebody is unhappy." (Jennings & Haughton, 2002, 240). In the context of meeting market expectations, Eisner's "lack of understanding" is certainly applicable to companies failing to ascertain what their customers want and to work toward providing it each and every time. The sad lesson being learned by more and more companies is that an unsatisfied customer will remain so only as long as it takes to find a new supplier.

Exhaustive research has been focused on ways in which companies can improve the quality of their goods while at the same time reducing both the cost and time required to produce them. Companies have implemented improvement methodologies to identify and eliminate waste from their processes, to increase the speed of production, to identify and correct defects at their point of origin, and to find less expensive materials from which to fabricate their products. However, one item that is often missing from mainline production improvement programs is that of introducing new products to market in a timely manner. In a fiercely competitive marketplace companies are often faced with two choices: either be the leader into a new product market or follow the leader and be faced with playing catch-up to gain acceptable market share. Success, then, lies in a company's ability to perform the following tasks:

- identify a consumer need (or want)
- design a product to fill that need
- produce an engineering prototype of the new product for test and evaluation
- if acceptable produce the new product for distribution to meet the consumer need, **and**
- do all these things before its competitor(s).

Even mature companies securely entrenched in their markets must continually strive to meet consumer expectations for products that are newer, better, stronger, lighter, more fuel efficient, more environmentally friendly . . . and the list goes on. Companies trying to avoid being overrun by their competition focus tremendous effort on bringing new products to market faster than ever before.

In the earliest stages of introducing a new product, modern computer assisted design (CAD) applications allow engineering research and development to proceed at an amazing pace. Design changes can be made and distributed electronically for approval from an engineer's desktop in a fraction of the time it would have taken to route paper copies just a few years ago. Modeling software allows designers to view graphical representations (both stationary and in motion) before any materials are purchased or production assets are committed. At this stage design changes can still be made at a relatively small cost. After a successful product launch, modern materials management and manufacturing tools have been developed to speed the production and distribution of new products. But somewhere between what has traditionally been labeled product design and the release of a product to manufacturing lies the often overlooked phase of producing engineering prototypes. Prototypes are essentially just models of products or services that allow designers to verify their intended functionality. If prototype evaluation demonstrates acceptability, the prototype then becomes the basis for production items. In reality the development and production of prototypes are still a part of the design stage of product development. Bedworth, Henderson, and Wolfe (1991) point out that "as much as 70% of the production costs of a manufactured part are determined during the engineering design process . . . therefore, only 30% of the part's cost is subject to money-saving efforts during the manufacturing planning stage." (p. 72). It has also been estimated that as much as 70 to 80 percent of a product's total lifecycle cost is determined during its design cycle (Schaeffer, 2002, 13). With so much cost being predetermined before a product ever makes it into production, it is of vital importance that every aspect of the design cycle be examined for improvement opportunities. The design phase of new product introduction has been described as an "iterative process consisting of six phases:

1) Recognition of need
2) Definition of problem
3) Synthesis
4) Analysis and optimization
5) Evaluation
6) Presentation" (Bedworth et al., 1991, 75).

Of these six steps, the evaluation phase is the first to engage personnel beyond the design engineer(s). During this phase engineering prototypes are fabricated to allow designers to test their theories under real-world conditions and revise design parameters found to be inadequate. Thus, fabricating and testing engineering prototypes are a part of the product lifecycle where the most significant gains can be made in cost reduction. This coupled with the ability to make quality improvements at such an early stage of product development make the prototype phase an ideal place to focus improvement efforts.

Of necessity, prototype production involves material procurement and some level of assembly and test effort. This stage of design bears striking similarities to full-scale production operations. The purpose, then, for this course is to examine these similarities and determine if they share enough common ground to allow the exchange of tools and practices between them to help relieve the 70% to 80% cost burden described above.

<u>What will be Studied?</u>

Increasing competition in the marketplace has forced companies to make real, substantive changes in the way they operate. The goal sought by today's industrial leaders is world-class performance. Schonberger (1986) asserts that the main goal of world-class manufacturing can be summed up in the words of the Olympic Games motto: "*Citius, altius, fortius*. From the Latin the English translation is 'faster, higher, stronger.' The world-class manufacturing equivalent is *continual and rapid improvement*." (p. 2). He further emphasizes the importance of

> a full range of elements of production . . . management of quality, job classification, labor relations, training, staff support, sourcing, supplier and customer relations, product design, plant organization, scheduling, inventory management, transport, handling, equipment selection, equipment maintenance, the product line, the accounting system, the role of the computer, automation, and others. (p. 1).

New products face an uphill climb to world-class success on their journey from initial design concept all the way through to end item delivery to customers. To ensure success of new products, every phase of their development must be scrutinized to identify potential areas of improvement. Waste must be identified and eliminated (in both materials and labor) to improve profit margins and delivery times. Processes must be fine-tuned to achieve throughput targets. In recent years, extensive research has gone into developing process improvement methodologies to assist companies with their improvements. Computer-Aided Design (CAD) systems have been developed to assist designers with converting product ideas to reality, thus, greatly reducing the time between when a new product idea is conceived and when it actually enters production. Many successful firms have adopted concurrent engineering practices as a means to allow time-critical design functions to be carried out simultaneously. Equally important are tools that have been developed to help companies improve their methods of manufacturing new products. Resource planning tools give managers and planners the ability to review production requirements (including human resources, materials, equipment, facilities, etc.) and to plan the most efficient use of each resource. And for the post-production phase of a product's lifecycle, improvements have been developed for finished goods inventory and distribution to ensure that the products make it into the hands of consumers with the least amount of delay and cost.

Development of these improvement methodologies and tools have resulted in drastic reductions in time to market, quality improvement rates never before imagined, and cost reductions once thought unachievable. However, one area of largely untapped improvement potential is that of producing engineering prototypes. Once a new design has reached a reasonable level of stability it is desirable to have prototype models fabricated for test and evaluation prior to releasing the product into the manufacturing cycle. Generally a small number of prototypes are produced and subjected to various levels of inspection to determine, first, that the design concept has been accurately captured and, second, that the samples are functionally acceptable. This phase of new product development is iterative in nature. Flaws detected in prototype units are corrected, sometimes new features are added, new prototypes ordered, and the testing begins again. This process continues until engineering is satisfied with the results and releases the design to manufacturing. This course explores process improvement opportunities applicable to prototype development and production. Emphasis is placed on identifying those tools originally designed for other areas of production that may be appropriate for transfer to the engineering prototype phase.

Scope of the Study

The latter part of the 20th century saw an intense interest among the manufacturing community in achieving World-Class Manufacturing status. The process of introducing new products to the marketplace was scrutinized from every conceivable angle to identify improvement opportunities. Benchmarking partners teamed up to identify best-in-class methods to be emulated in their own improvement efforts. The results were leaner, more agile, companies ready to face the competitive challenges of 21st century markets. The methodologies that have led companies to success in developing, manufacturing, and marketing new products in recent years have been amply documented. Tools have been developed to assist engineering with upfront research and development processes. Tools have also been developed to assist factory planners, managers, and engineers with the design and operation of manufacturing processes. Tools have been devised to assist with supply chain management. And still more tools have been developed to aid in raw material and finished goods inventory and tracking.

This course examines many of the tools that have been most successfully developed for these areas to determine their applicability to the engineering prototype phase of new product introduction. The production of engineering prototypes shares similar processes with other areas of the overall manufacturing cycle. In effect, engineering prototype production is a microcosm of the greater product manufacturing cycle yet has been largely neglected in terms of process improvement strategies. Yet, the similarities between prototype production and full-blown factory production will provide a framework of comparison for this course.

Glossary

Following is a list of terms used throughout the course as defined in a manufacturing context.

Approved Parts List (APL): The APL is a list of components approved for use in the manufacture of a company's sellable merchandise. Approval is generally based upon a series of qualifying activities including, but not limited to:

- Review of a supplier's manufacturing capabilities, quality management processes, and cost structure
- Evaluation of a part's ability to function as designed and advertised, in the intended application, and under the expected worst-case operating conditions
- Verification of a part's compatibility with a company's current and expected manufacturing processes.

Benchmarking: The process of "identifying, understanding, and adapting outstanding practices from others, in order to improve your own performance." (O'Dell & Grayson, 2000, p.2).

Computer-Aided Design (CAD): A design process that "involves the use of computers in creating or modifying the product design" (Amrine, Ritchey, Moodie, & Kmec, 1993, p. 119). The term is used interchangeably to refer to both the process and the software used.

Data: "Raw facts about the organization and its business transactions." (Whitten & Bentley, 1998, p.37). More often than not, data by itself has little meaning.

Design: "All activities which transform a collection of inputs into a product satisfying a need." (Bedworth, Henderson, & Wolfe, 1991, p.134).

Information: "Data that has been refined and organized by processing and purposeful intelligence." (Whitten & Bentley, 1998, p.38).

Just-in-Time Manufacturing: A manufacturing philosophy focused on providing a work center with its required resources (manpower, material, equipment, etc.) when it needs them and not before.

Lead-Time: A period of time spent waiting for an outcome of one process prior to the start of another. For example, when a component part is procured the time between the decision to make the purchase and the actual delivery of the part is know as the procurement lead-time.

Lean Manufacturing: A manufacturing philosophy that focuses on identifying waste in every manufacturing process and systematically removing that waste. A major focus is made on removing "wait" times associated with production and creating an environment where all process time is actual "hands on" time.

Material Requirements Planning (MRP): A computer-based information system developed to handle scheduling and ordering materials needed for production. An MRP system is designed to convert a production plan for a specific number of assemblies into purchasing requirements for components and/or raw materials by working backwards from the actual due date and taking into account individual material lead-times.

Manufacturing Resources Planning (MRP II): MRP II can be thought of as a second generation MRP system that goes beyond materials planning to include business planning, production planning, and incorporate the master production schedule of a factory.

Operations Management: "The management of systems or processes that create goods and/or provide services." (Stevenson, 1999, p.4).

Reengineering: A "planned redesign of all or part of a process" (AT&T, 1991, p. v) intended to bring about order of magnitude improvements in the process.

Theory of Constraints (TOC): An operation philosophy that focuses on identifying and eliminating the bottlenecks in a process. Bottlenecks are the constraining items in a production system. The theory holds that removing the worst constraint in the system will cause another constraint to surface as the worst. Repeating the process continually improves product flow in a factory.

Total Quality Management (TQM): A quality improvement methodology stressing the need to continuously improve every aspect of a business process in order to effect greater customer satisfaction.

Work-in-Process (WIP): A measure of the amount of material that has left raw material stock but has not yet become finished goods. (Dewar, 2001, p. 5).

World-Class Manufacturing: This is a term generally used to describe the best possible manufacturing techniques when a company compares itself to any manufacturing industry in the world.

HISTORICAL BACKGROUND

A full appreciation of the importance of streamlining the New Product Introduction process, particularly the engineering prototype portion, requires an understanding of the modern manufacturing environment and the requirements it places on every aspect of a product's life cycle. Today's American factory environment owes much to techniques borrowed from Japan's post-World War II industrial complex. A growing American trade deficit beginning in the seventies and continuing even to the present provided the impetus for examining what foreign competitors were doing better and faster than American industries themselves. Increasingly, during these decades of study, Japanese factories became the focus of intense scrutiny by investigators seeking to unlock the keys to their success. As the results of these studies were published, American managers began to emulate what were deemed the best Japanese practices in an effort to regain lost market share.

In today's global economy, these borrowed techniques are undergoing constant review and revision to ensure that every possible competitive advantage can be achieved. The following section provides a study of some of tools that have been developed in response to these decades of study and have been successful in reshaping the modern manufacturing landscape. These tools, although generally developed to exploit the full potential of a production operation, will be demonstrated to have similar applicability to the production of engineering prototypes in support of new production introduction.

REVIEW OF THE TOOLS

Following is a review of some specific tools and techniques that have been developed in efforts to make modern manufacturing operations the very best they can be. Obviously an examination of every tool's development and success would far exceed the scope of this course. Instead a representative subset of the tools will be presented along with their native manufacturing setting as the frame of reference. Then each tool will be evaluated for it's suitability for use in the production of engineering prototypes. Appendix A provides a more detailed view of the tools in tabulated form for further reference.

Quality Circle

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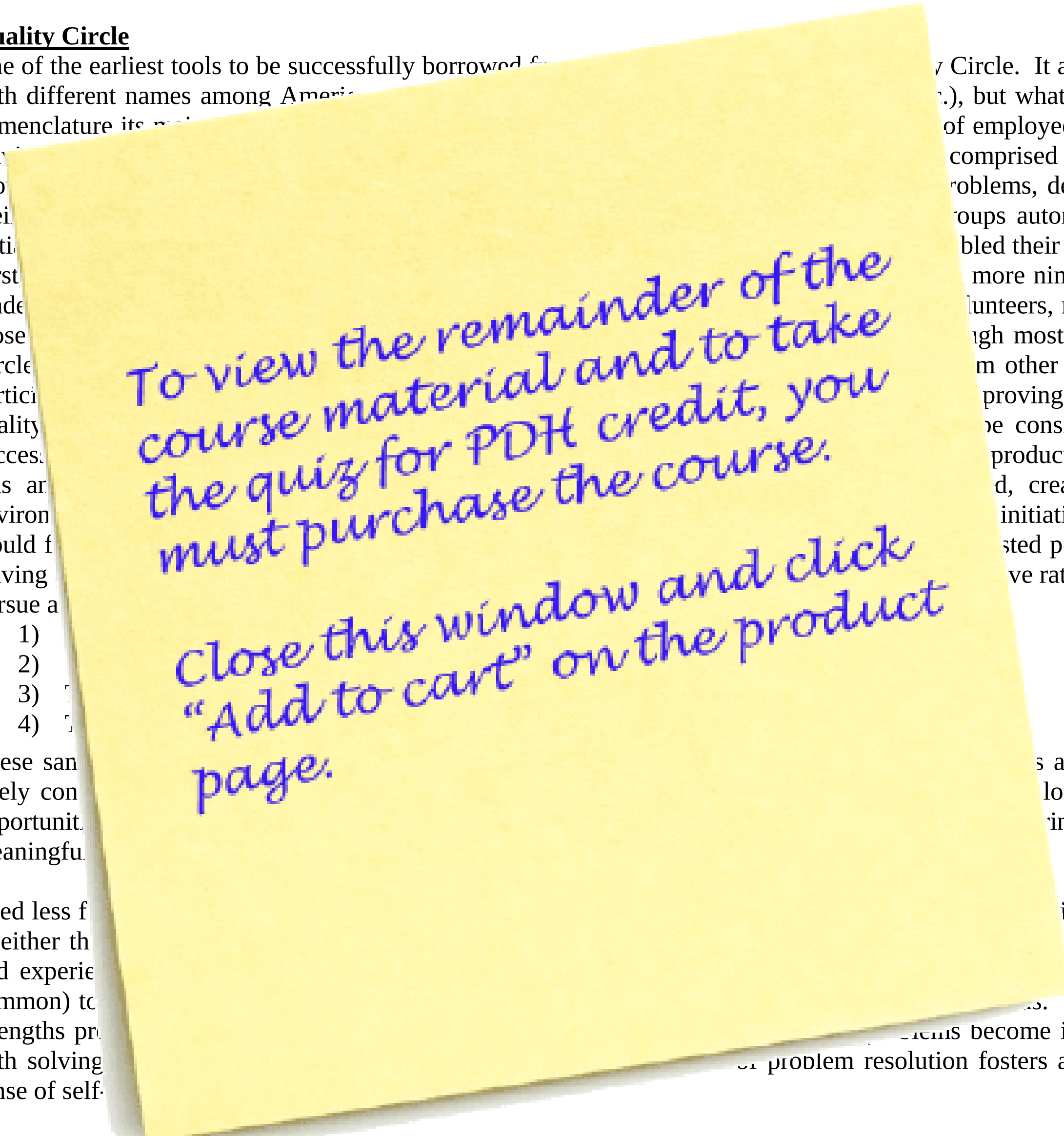

The basic application of quality circle concepts to released-item production is relatively simple. Full-scale assembly generally involves multiple workers performing similar operations. Gathering a team of these workers allows a comparison of multiple viewpoints of the same operations. This provides for dialogue to discuss multiple solutions to perceived problems. Prototype assembly, on the other hand, is generally carried out by one or a few workers performing a wide range of dissimilar operations. A basic scenario begins with design engineer creating a preliminary schematic or assembly sketch of a product and delivering it to an assembler. The assembler gathers the raw materials (or components) necessary to assemble the prototype. These materials may be procured by the engineer, the assembler, or by someone designated to manage an engineering materials stockroom. Once the materials are available, the prototype is assembled and tested as prescribed by engineering.