NSE TECHNICAL TRANSACTION Vol. 42, No. 1 January – March, 2007 Harold U. Nwosu

Encouraging Innovation and Cost-Cutting Programs in a Developing Economy

By

Harold U. Nwosu
Mechanical Engineering Department
University of Port Harcourt,
Port Harcourt

ABSTRACT

Successful companies continuously face the challenge of designing new products that are more durable, yet less expensive, than their predecessors. Truly, low-cost manufacturing requires that ease of manufacture, assembly, and service become part of the product's initial design specifications. Manufacturing engineers must have early and continuous involvement in the design process. Also, design and manufacturing engineers must respect each other's area of expertise. Finally, manufacturing input should not be a set of constraints, but part of a dialog that sets the stage for reaching agreed-upon goals. It is easier to cut costs when engineers work with production rather than against it. This paper discusses how breaking down barriers encourage innovation and cost-cutting in a manufacturing environment.

INTRODUCTION

Manufacturing is changing from a mechanical device to an information system. Historically, manufacturing is evolving from being dependent on human labour and intelligence to relying on machine intelligence. Managing manufacturing means managing information, continuous change, and time, rather than the traditional management of people, space, materials, tools, inventory, and costs. Manufacturing is fast becoming a science-based culture with great potential for change that goes well beyond today's technology. Engineering the manufacturing system requires scientific and technical capabilities that are much further advanced than what most engineering graduates possess. Manufacturing requires both individuals and organisations that are capable of combining and using rapid advances in materials sciences, lasers, process operations, control theory, and artificial intelligence, with the visionary application of computer and communications technologies, and information science techniques.

World trade can no longer be ignored by any manufacturer. Computers and communications technologies have contributed to the globalization of markets and competition. Markets have become fluid and fragmented, an independent economy has been replaced by the reality of interdependence. The implications of these are twofold. First, automation for high process reliability and consistent product quality is needed to offset labour cost advantages in newly industrializing competitor countries. The second, and more important implication is that the flexibility provided by the computer is necessary to be competitive in terms of customer service.

In an oligopolistic and domestic market, a firm could anticipate and respond to the moves of a limited number of competitors in traditional ways, but this becomes nearly impossible if competitors from many countries must be considered. The competitive manufacturing firm of the future needs to be able to shift product mix and functional attributes rapidly in response to competitors entering into and dropping out of the market.

Manufacturing technology and the globalization of markets have led to the reevaluation of the importance of manufacturing and its potential contribution to the competitive strategy of firms in a developing economy. A new atmosphere of vitality and vigor in manufacturing and production operations can be observed in in0dustry and the universities. Applying the computer to manufacturing is the method by which solutions that reduce production costs and increase flexibility in product design and mix can be found. We know the importance of World Class Manufacturing (WCM) and its major tools: Computer-Integrated Manufacturing (CIM), Total Quality Control (TQC), and Just-In-Time (JIT) production. We also know that for successful WCM implementation, the senior managers of a company must work as a team (Ransky, 1992).

THE DESIGN CHALLENGES FOR INDUSTRIES IN A DEVELOPING ECONOMY

Demand for smaller, low power, low cost, reliable products is attracting and will attract more competitors than ever before.

Competition will be fierce with many new entries into the market. The key goal will be cost effective "reliable" products with the emphasis on "reliable." If one is to maintain market share, current and future products must be reliable and be equal to or better than the competitions. Succeeding in that goal against major competitors will be a severe challenge. How can one improve reliability? There is no simple answer, but in the purist sense, the responsibility starts in design. By simple mathematics, product reliability will be no better than the sum of the failure rates of its component parts, which are all defined by engineering. Obviously, the design challenge is then optimizing the conditions for reliability.

In order for engineering to design for reliability, it is necessary to understand the parameter interaction, which give success or conversely failure. The number one prerequisite of design is to do sufficient analytical design and, or testing to thoroughly understand all interactions impacting reliability. Without understanding, crisp specifications don't occur. In many cases fundamentals are forgotten in the rush to make hardware. For every good analytical job, there are two or three that are inadequate. There is always room for improvement. The Japanese are excellent in analyzing the conditions which give success or failure. We all know what the Japanese did in many industries. They displaced competition with a quality cost effective product. The demands for next generation technology will disallow leaving anything to chance.

Functional product reliability will be only as good as the margins designed into it, whether that reliability can be realized is dependent on how well relevant specifications are identified and associated testing executed. Analysis usually doesn't go far enough, the tendency is to stop once the first few items of whatever design have been completed and tested. The tendency is to ignore the statistical nature of the problem and leave yield concerns to manufacturing and quality assurance (Q.A.). How many in their design cycles have taken 3s limit components and verified that hardware does in fact operate to spec under those worst case conditions? How many of the imposed engineering specs have a known relevancy to function? How many are too loose or how many are too tight. How well are the specs thought out and reviewed to insure there is a consistent funneling action which allows product flow rather than hinders it? How many areas have no specs at all, but rely on past informal documentation? (Ealey, 1989).

The product of engineering activity is a specification which in turn is based on analysis. Let us not forget that basic fundamental. If in designing for reliability, excellence in specifications and analysis is the first prerequisite, then the second is excellence in test equipment and testing. A specification without a practical test isn't worth the paper it's written on. More than once, engineering has written specifications for which there is no practical test. Furthermore, in certain key areas, it is absolutely essential that engineering define the test technique and circuitry required to satisfy spec intent. I recall only too well past experiences, where manufacturing had constructed read/write head test equipment for hard drives only to find that heads tested on that equipment, and which met spec according to the equipment, would not perform in the product. Why? Because the manufacturing tester bore no resemblance to the engineering breadboard from which data was collected to provide the spec values. Specification and test definitions are inseparable. The cognizant design engineer must be responsible and accountable for both. Engineering follow through must occur to insure the production test hardware doesn't prostitute engineering spec intent (Nwosu, 1991).

Again, having adequate test equipment and test coupled with engineering follow through and concern is the key to making things work. The concern must be enough to follow some sample quantity into reproduction or production to see that the test is adequate and that piece part flow occurs with reasonable yield. How many designers are concerned with knowing first run yield of their design in the factory? Do you have the concern to ask the question "How is my part of the design working in its application? As my design flows into production, does the test I defined do the job in sorting good from bad?" or is the attitude, that is someone else's problem. Where we are heading tomorrow in technology disallows attitudes which attempt to sluff off responsibility for completing the job. Knowledge of the designer on the necessary test equipment and tests is absolutely necessary to insure proper factory control. The feeling is that the design engineer should be required to support the factory in his or her area of responsibility until enough factory flow occurs to prove that the specs and testing are adequate.

Another problem in testing and test equipment is defining test hardware which is repeatable, calibratible, and reliable. Typically, internally designed test hardware and software do not receive adequate scrutiny concerning their ability to satisfy spec intent. Test hardware often does not have adequate repeatability nor can be easily calibrated. With the tight margins and tolerances expected in future products, there is no room for anything less than precision and excellent in the test equipment which will be controlling our factories.

Up to this point, we have discussed analysis, specs and testing which go hand in glove in the pursuit of reliability. Analysis gives us insight into the failure modes associated with our designs. From that insight comes the knowledge against those conditions which could cause failure. From those specs evolve the test equipment and procedures which insure reliable piece part flow. The ultimate result of our effort is a successful product. How reliable that product is depends on how disciplined we have been in executing the design and insuring operating margins exist. How successful we have been in that pursuit depends on how great is our desire to pursue excellence, and our commitment to settle for nothing less.

The third prerequisite for reliability is then an attitude and philosophy which settles for nothing less than excellence. Without the proper attitude and a commitment to excellence, weak links can occur which compromise product reliability. It does little good to do an excellent design job on 90% of a product if the remaining 10% causes excessive failures. The total design is no better than the weakest link in the reliability chain. We need to make a conscious effort during design to define failure modes for both hardware and components, and define test to verify those failure modes and establish failure rates.

We can ill afford to design products with worse failure rate than their predecessors. Again, the basic ground rule is, we must be equal or better. We must change any attitude which do not accept reliability as a design responsibility. Engineering philosophy needs to be directed at pursuing simplicity in design, and as an on going commitment ask the question, "Is there a simpler way?" The criteria for success must be established in terms of realistic tolerance allocations in each design area such that satisfying those allocations insure success. All the prior statements encompass the normal design process and provide an inherent reliability figure which is engineering's responsibility. Reliability will be no better than the inherent reliability designed into the product, it can only be worse.

How close reliability figures approach the inherent capability depends on the team effort between Engineering, Manufacturing, and Q.A. Again, the attitude and commitment must exist at both the design and management level, or the needed reliability won't happen. Therefore, what is needed in Dr. Deming's words, is to work smarter, not harder. We must collectively put in place those disciplines which will permit us to work smarter. This is then the design challenges for engineers and designers. Engineering management must put in place the operating framework which support and demands excellence directed at achieving reliability. Whether this takes form by implementing design standards, chronic failure mode checklists, reliability design reviews reliability assurance groups within design, or what ever, the task must be started. Without total management dedication directed at defining such a framework, it won't happen. Everyone needs to contribute to that definition and to share ownership (Scherkenback, 1986).

DESIGNING FOR MANUFACTURE AND ASSEMBLY

Historically, products have been put together by people, who can see, touch, and contort their hands. Parts and subassemblies have therefore been designed to take advantage of dexterous labour. Now with a growing work force of automations, the rules of design are changing. Products are being simplified to accommodate nonhuman assembly. Manufacturers have invested millions in production machines that are essentially blind, move in only a few directions, and are not particularly sensitive. In order to make this investment pay off, products may have to be redesigned to accommodate the characteristics of robots, automated machine tools, and other related labour-saving apparatus (Ransky, 1990).

There are several definitions of Design-for-manufacture-and-assembly (DFMA) techniques, but they all center on the idea that production factors must be taken into consideration at the very beginning of the design project. DFMA can be defined as a methodology that, early in the design process, addresses all the various factors that can impact production as well as customer satisfaction. DFMA is a collective term for a range of considerations dealing with product design, manufacturability, material selection, and assembly. It is sometimes used interchangeably with the terms Design for manufacture (DFM), Design for assembly or Design for automation (DFA)

Design for assembly derives its name from recognition of the need to consider assembly problems at the early stages of design. It entails the identification of the most appropriate assembly system for a new product design. This is done in conjunction with a careful structural analysis of the design, to determine the design's overall efficiency and suitability for the chosen assembly method. Design for manufacture, which centers around identifying the appropriate materials and manufacturing processes, can be categorized as two types: component (or part) DFM, and product DFM. The former represents only the fine-tuning process undertaken once the product form has been decided, whereas the latter attacks the fundamental problem of the effect of product structure on total manufacturing. The merger of the terms under the banner of DFMA evolved from industry's growing interest in conducting design and total cost analysis together with materials and process selection.

While experts disagree about how to measure the impact of automation on production, when it comes to design rules required of companies moving from manual to automatic assembly, there is widespread agreement. The first rule cited by advocates of design for automation is, reduce the number of components wherever possible. The logic is very simple: trim the number of parts that have to be assembled and product costs are reduced. At the same time, you pare inventories, cut the number of suppliers that you have to deal with, and shorten the production cycle time. Of the various parts designer may eliminate, fasteners are most important. Every one taken out of the assembly process does a great deal to streamline the production cycle. Screwing two things together, for example, requires aligning the parts, inserting the screw and washer, changing the end effect or to a screwdriver, and then changing it back. One can save a lot of time by making a single part instead of having to put two together (Childs, 1984).

Another rule of DFA is, assemble in layers. One thing to avoid, if at all possible, is lifting or turning a part. One can do that by designing subassemblies with each component stacked on top of the other. The robot's motions stay simple, and you don't need a gripper capable of picking manufacturability, material selection, and assembly. It is sometimes used interchangeably with the terms Design for manufacture (DFM), Design for assembly or Design for automation (DFA)

Design for assembly derives its name from recognition of the need to consider assembly problems at the early stages of design. It entails the identification of the most appropriate assembly system for a new product design. This is done in conjunction with a careful structural analysis of the design, to determine the design's overall efficiency and suitability for the chosen assembly method. Design for manufacture, which centers around identifying the appropriate materials and manufacturing processes, can be categorized as two types: component (or part) DFM, and product DFM. The former represents only the fine-tuning process undertaken once the product form has been decided, whereas the latter attacks the fundamental problem of the effect of product structure on total manufacturing. The merger of the terms under the banner of DFMA evolved from industry's growing interest in conducting design and total cost analysis together with materials and process selection.

While experts disagree about how to measure the impact of automation on production, when it comes to design rules required of companies moving from manual to automatic assembly, there is widespread agreement. The first rule cited by advocates of design for automation is, reduce the number of components wherever possible. The logic is very simple: trim the number of parts that have to be assembled and product costs are reduced. At the same time, you pare inventories, cut the number of suppliers that you have to deal with, and shorten the production cycle time. Of the various parts designer may eliminate, fasteners are most important. Every one taken out of the assembly process does a great deal to streamline the production cycle. Screwing two things together, for example, requires aligning the parts, inserting the screw and washer, changing the end effect or to a screwdriver, and then changing it back. One can save a lot of time by making a single part instead of having to put two together (Childs, 1984).

Another rule of DFA is, assemble in layers. One thing to avoid, if at all possible, is lifting or turning a part. One can do that by designing subassemblies with each component stacked on top of the other. The robot's motions stay simple, and you don't need a gripper capable of picking the assembly up. One could do the same for fasteners. Keep all these vertically oriented, and you'll only need to invest in a robot capable of coming at these things from one direction. A third principle of DFA is that of adding nonfunctional features to parts (orientation points, guide pins, and chamfers), if they will make the robot's job easier. Therefore, a qualitative approach to DEMA, such as the suggestions below, provides good advice to product designers (Stark, 1989):

1. Minimize the number of parts.
2. Minimize assembly surfaces.
3. Design for two-axis assembly.
4. Improve assembly access.
5. Maximize part compliance.
6. Maximize part symmetry.
7. Optimize part handling.
8. Avoid separate fasteners.
9. Provide parts with integral "self-locking" features.
10. Drive toward modular design.
11. Avoid mixtures of process technologies.
12. Specify piece-part packaging compatible with factory material handling and automation schemes.

While automation does introduce new challenges for designers and production personnel, an organization that learns to design for automation will see the results on the bottom line. Production will go more smoothly and quickly, the capacity of a plant will increase, and the cost per unit of finished goods will drop. The key thing manufacturers have to realize is that they face a management problem that cannot be solved merely by spending more money on engineering. The benefits of automation will not naturally follow from an increase in the design budget; they result from a series of changes in production that flow through the entire plant. The payoffs, costs, and risks must be carefully assessed so that a manufacturer can make rational investments in automation.

Changing the design of a product, especially midstream (in its life cycle), will involve a substantial investment of time and money. A manufacturer may have to retrain workers, retool machines, and completely rearrange its production line. Before doing that, a company should make sure it knows what it's going to change, and how it's going to do it (Tompkins, 1989).

ENCOURAGING INNOVATION AND COST-CUTTING

To create a working environment that encourages both design innovation and cost cutting, it helps to have a corporate champion. He is an individual in upper management who models and supports risk-taking, innovation, customer awareness, open communication and cost consciousness. Other important factors include:

1. Have design and manufacturing engineers work in close proximity, where they will have plenty of chances for informal give and take.

2. Eliminate formality. Small-scale, effective cost cutting often takes place as a result of informal, small-group activity.

3. Encourage debate. A consensus reached too quickly may indicate that alternatives have not been explored sufficiently.

4. Find ways to use your own products. If you cannot make them part of your production or design system, then set up a lab, develop an employee purchase plan, or donate products to a local user who can provide feedback.

FORMING A TEAM

Many companies have subtle, built-in obstacles to making low-cost products that must be identified and eliminated. These include disagreements between design and manufacturing departments, poor scheduling between a company and its suppliers, and misunderstandings between the company and its customers' needs. Removing barriers between design and manufacturing engineers begins with open communication. Such a situation was faced in the development of a particular product from one company. The experiences from gained that project serve to illustrate the basic tenets of a cooperative design and manufacturing effort.

The basic requirement for the product was that it runs five times faster than its predecessor, while offering additional features. Meanwhile, its price goal was 20% below the predecessor's introductory price. Faced with a seemingly impossible task, the company quickly realized that manufacturing had to be approached from several directions. For example, some terminal makers substantially reduce costs by automating the assembly process. Others improve morale on the line, and still others design with fewer, simpler parts.

These three approaches were combined, and close cooperation between manufacturing and design engineers was emphasized throughout the program. Data from both departments were integrated, and significant assembly, inventory, and purchasing reforms were made. Some programs to promote teamwork were already in place; for example, all new division employees work on the production line for at least one day. Also, a mentor program teams each new employee with an experienced worker, often from a different functional area. For instance, a designer may serve as mentor to a manufacturing engineer. This program helps new employees absorb corporate culture. It also shows them how other departments perceive their group and teaches them how other groups fit in.

With such programs as a basis, a small, multidisciplinary design team was formed to develop the product. From the product proposal stage forward, this team included design, manufacturing, test, and reliability engineers. The team worked in harmony to design the product and the production process simultaneously. Manufacturing personnel were not only present in design meetings, but some of them also moved their desks into the design area. Being with the designers on a daily basis allowed manufacturing experts to become part of an informal decision making process that goes on outside formal design review meetings. They were free to challenge anything, and their challenges were welcome. In addition, they identified the cost and reliability implications of design decisions.

Manufacturing engineers also designed a self-test sequence into the product's circuitry. These internal tests cut costs by replacing external automated test equipment on the production line. Field-service technicians also run the sequence to troubleshoot problem. In addition, an abbreviated set of routings runs automatically each time the product is turned on, to aid fault detection. The manufacturing organization also managed product reliability and telephone support of field service technicians.

In addition, they managed a special group called hardware-sustaining engineering, which is responsible for problems that arise during production. For example, if a supplier cannot produce a needed part, this group is responsible for helping the supplier produce the part or finding an alternate supplier. Sustaining engineering also works with design to correct problems found on the line. This again strengthens the ties between the two departments and is only one way that both are involved in production. In addition, designers analyze reliability issues and determine the root cause of problems.

Design and manufacturing also develop the manufacturing process together. Problems then can be caught earlier than before. Design takes the lead if problems are found before going into manufacturing; manufacturing takes the lead in resolving problems that arise on the line or later. For example, when a problem concerning a socket caused a 5% intermittent failure rate, an *ad hoc* team of reliability, design, component, process, and assembly people was formed. Engineers determined that the primary problem was with the socket design.

Then, a technician developed a new tool that would install the component into the socket reliably, and the supplier made changes to correct its process. The team also implemented several other processes and procedures. The design team optimized the product for reliability, manufacturability, power, and speed. They cut the total number of parts. Snap-together parts eliminated fasteners, and parts were designed so they could be used in other terminals. Parts in use were listed, and each proposed new part was identified and treated as an exception. Decision to use new or existing parts were made on an individual basis, rather than by formal guidelines.

The design team also eliminated as many hand-inserted parts as possible. Socked parts, parts that were not hermetically sealed, and others that could not withstand the high temperatures and hot-water wash of the solder-flow process were used only when there was no alternative. Minimizing such parts and using more automation reduced assembly time because fewer workers were needed and assembly procedures could be changed quickly.

COMMON GOALS

Sharing the common goal of wringing out product costs makes it easier for manufacturing and design engineers to work together. To develop low-cost product designs, engineers must weigh decisions as carefully as if they were running their own business. Typically, manufacturing engineers see the relationship between their work and the bottom line because their performance is rated according to business indicators such as finished-goods inventory, quality, and customer-satisfaction ratings. But design engineers are primarily rated on how well they meet specifications, schedules, and budgets, not on how well their products sell.

At this particular company, engineers and manufacturing employees attend a workshop where they learn to analyze division performance indicators and summarize them at group meetings. Expanding the engineer's role to include customer involvement further enhances his ability to evaluate trade-offs among features, design alternatives, and product cost. Also, a company has an added advantage if it uses it own products.

Although manufacturing engineers have the main responsibility for supporting field-service technicians, they call in design engineers when problems are serious or difficult to pinpoint. This provides designers with opportunities to check a product's reliability and its ease of service, both major factors in determining lifetime product costs. When manufacturing and design engineers both understand user requirements, cost management becomes integrated throughout the product development cycle. If cost issues and estimated part costs are reviewed monthly or even weekly, beginning in the product concept stage, cost overruns become less likely.

ON-THE-FLY COST CUTTING

Open communications and informal structuring help to create an atmosphere where cost cutting flourishes. Developing a design that meets all criteria, including low manufacturing cost, depends on open debate. In a formal, closed system, problems tend to be glossed over. This limits debate, and the design suffers. In a less rigidly structured organization, design engineers get manufacturing input early and often. They can then base design decisions on cost and manufacturability criteria.

When a company first implements design-for-manufacture methods, relatively few changes can bring big savings. As time goes on, cost reductions are more likely to result from small adjustments. These small reductions come about through awareness of customer requirements, development of alternative ways to meet them, and informal, daily communication be between manufacturing and design. If the corporate culture promotes cross-functional teamwork and encourages employees to challenge the way things get done, cost cutting becomes easier.

WORKING WITH SUPPLIERS

Many manufacturers rely on suppliers to supply parts. Therefore, barriers between the company and its supplier should also be removed to improve manufacturing. As all parts of an organization should share common goals and assumptions, so too should companies and their suppliers. At this company, key suppliers were brought into product planning at the concept stage. Suppliers providing new, modified, or high-cost components were brought in early for iterative design work. Some supplier partnerships already existed, but the company also worked with new suppliers to spell out expectations and set mutually beneficial common goals.

An emphasis on communicating by phone and fax puts engineers at the company and its suppliers on first-name basis. Regular review sessions are held at least quarterly with major vendors where engineers share information. For example, when tests identified solder problems with a major part, a team of soldering experts spent several days with the supplier's engineers, providing training and process engineering consultation to resolve the problems.

DESIGN INTO REALITY

The design and data depend on a strong, efficient manufacturing operation to turn them into reality. The manufacturing operation could be streamlined throughout the development of the product. Twenty percent fewer suppliers could now supply parts, and the division could work more closely with those remaining. A just-in-time delivery system could be incorporated. Each supplier could be evaluated to identify where the opportunities for greatest gains lay. With some suppliers, the goal could be to reduce delivery time to 12 weeks from 16. For other suppliers, it could be a matter of fine-tuning, perhaps bringing the supplier's suppliers into JIT.

Many suppliers could make daily visits to deliver needed components. They deliver those parts on custom-designed, movable storage carts directly to the point of use. The padded carts eliminate both special packaging and much of the labour and expense of packing, unpacking, counting, and weighing incoming items. In one extreme case, an IC manufacturer had employees working at the division facility delivering parts as they are used. Each product on the assembly line includes a card signed by the individuals who build, test, and package it. These cards ask for customer feedback. The company corrects any problems reported and occasionally also checks with people who rank it highly. This positive feedback is shared with manufacturing and design. Several programs, ranging from ten-minute review sessions to on-going teams, help employees share their knowledge and put it to work. Goal-directed problem solving now goes on at all levels of the organization. Risk-taking and questioning are encouraged.

INTEGRATED DATA BASES FOR CAD/CAM

Integrating design data into manufacturing planning and assembly is important to low-cost manufacturing. Recent advances in desktop computer technology will probably benefit engineers more than any segment of the end-user community. Since the introduction of the microprocessors, engineers are finally getting the computing power they need on the desktop. Most engineers were skeptical of the personal computer and considered it a toy rather than a useful tool.

Nevertheless, some early adopters started using personal computers for engineering work and found that, if they were patient, they could run small finite element analyses or equation solvers or create simple machine and conceptual design drawings. Unfortunately, the more complex tasks still had to be carried out on expensive minicomputers and mainframes with limited resources and access. This meant that a considerable amount of engineering work was still performed by hand, using calculators along with pencil and paper.

These limitations are rapidly disappearing. Fully configured desktop workstations are now available. These machines have the power to solve most engineering problems that were once solved on expensive minicomputers and mainframes. The wide availability of desktop workstations means that thousands more engineers will gain access to computing resources, and will be able to solve more problems by computers than ever before. As a result, small engineering firms with small budgets will become more competitive and be able to solve difficult problems that formerly had to be solved by laboratories or manufacturing giants. With these advances in hardware, there have been corresponding developments in software. Increased computing power has enabled engineers to develop programs capable of solving problems that were once solved by physical testing and prototyping.

Networking is one area in which engineers have been a step ahead of the general office environment. Connectivity among various workstations using different types of software makes data portability a basic requirement in the engineering office. A design department may use a CAD program running on a microcomputer system, for example, whereas a solids modeler application running on a workstation needs to import that data from the microcomputer CAD system. The answer is direct data base conversion and the use of special file formats.

New design and manufacturing methodologies are another important outcome of network proliferation. Connectivity allows data to be transferred from the design department directly to the manufacturing floor to a numerically controlled machine tool. These capabilities, however, require new methods of design and manufacturing. Despite these advances in computer technology, a great deal of engineering work in most developing economy is still based on methods that have been in use for the last 40 years.

The basic principles of finite element analysis have not changed, for example, and finite element analysis is one of the most powerful, and often misused, forms of engineering analysis. With the growing access to desktop computers, many more engineers will have access to finite element analysis. This decade will be an exciting period for the engineering profession in Nigeria. Breakthroughs in computer technology will change the way products are designed, tested and manufactured in Nigeria.

Personal computers are being used with much greater frequency for a wider variety of design and production tasks in the engineering department and on the factory floor, primarily because the latest desktop hardware has much the same graphics capability, memory capacity, and processing power as conventional mainframes. Consequently, the same techniques that have been used for data base organization and management on large computer systems are now being applied to smaller computers. This development presents engineering managers with the opportunity to link all phases of the design process via a central, integrated data base system, helping them to maintain product quality and production cost at competitive levels.

As they have attempted to manage mainframe-size data bases on personal computers over the past years, engineers have increasingly focused their attention on process integration and management; design and production activities are linked with each other and with various management tools (like the critical path method, and program evaluation and review techniques), and some-times with expert systems. Because data bases are used for so many applications and activities, it is vital to distinguish between the project data base used, for instance, in the design of the space shuttle and similar systems, and the product data base used in the automobile and other industries

Engineering analysis programs typically perform many thousands of calculations to simulate physical phenomena. Two examples include calculation of moments of inertia and finite element analysis. The output of an analysis is usually displayed as an expressive graphical shape. Finally, the relative motion between links and parts can be simulated on a computer's screen before the real production process begins. Object movements can be animated to study the effects of factors such as vibration and speed on the performance of a design.

Computers are used in manufacturing operations to control and accelerate diversified tasks, helping decision makers to manage personnel, inventory, materials, equipment, and overall product quality. Process planning draws heavily on computerized equipment. In this case, sequences of operations are optimized to reduce production time and cost. When properly applied, computer-aided process planning controls the entire production process, from material handling through the different production operations, and ending with packing and storing stages. Finally, skilled personnel or intelligent machines check product quality using optical methods.

PRODUCT DESIGN AS A STRATEGIC ACTIVITY

Product design is not just an engineering responsibility. It should be a strategic activity that engages the entire firm. Company-wide product design roles are not only useful in projects, they are also beneficial to manufacturing, marketing, strategic planning, maintenance, and filed service. The manner in which product design is handled has a great impact on a firm's short- and long-range viability. Yet, in many firms, the product design process continues to follow antiquated procedures no longer adequate for the most important purpose.

Too often people get so involved with following "the procedure" that they lose sight of what they are trying to accomplish. The design process should develop products to meet pre-determined performance, logistical, and quality requirements. The product should also be produced at a competitive price, and help meet the firm's financial and planning goals. This requires close cooperation and input from a variety of disciplines.

Today, to be successful, product design must be accomplished using multifunctional teams representing every specialty in the firm. Different firms will need to emphasize different functions to suit their situation, but simultaneous engineering, or concurrent design, is both possible and necessary, and the tools and techniques are there to do it. Unfortunately, many traditional barriers still exist due to continuing fragmentation, sub optimization, overspecialization, and bureaucratic power struggles. Steps must be taken to tear down these barriers and promote a sense of cooperation. This can be initiated by developing a common understanding and commitment to the product's goals, and ultimately the firm's goals.

Design teams don't need to be large, there may be as few as four or five members for the smaller projects, and as many as 20 for large project. In any case, top management must totally support the design team concept. The teams must also have the authority and responsibility to establish and follow procedures. This power is necessary to assure that important factors are reviewed and appropriate decisions are made quickly. Factors often over-looked, such as assembly and maintenance features, manufacturing processes, product costs, and user interfaces, must be considered before the design is established. In the beginning, things should be flexible. After time, as concepts are devised, designs developed, tests conducted, and various decisions made, people begin to identify with particular configurations and it becomes much more difficult to make alterations.

Strategic product design is a total approach to doing business. To be successful, it must have top management's whole-hearted support and commitment. It should encourage managers, engineers, marketers, planners, and production people to identify and eliminate any barriers that exist so they can work as a team. This approach should identify conflicts and differences of opinion, which should be viewed as normal, and an early resolution encouraged. As the strategic product design culture is implemented, the various disciplines will learn to work more closely, and such conflict will be raised to more substantive levels. Perhaps most important of all, this type of management culture will enable each person to have more involvement and commitment in the products under design, and thereby make their jobs more challenging and enjoyable, and create the core technology base so vital to continuing success.

SUMMARY AND CONCLUSIONS

Low-cost manufacturing requires that ease of manufacture, assembly, and service become part of the product's initial design specifications. Many companies have subtle, built-in obstacles to making low-cost products that must be identified and eliminated. Removing barriers between design and manufacturing engineers begins with open communication. To create a working environment that encourages both innovation and cost cutting, it helps to have an upper management that models and supports risk-taking, innovation, customer awareness, open communication, and cost consciousness.

More and more products are being simplified to accommodate nonhuman assembly. Parts and subassemblies have been designed to take advantage of dexterous labour. Now, with a growing work force of automations, the rules of design are changing. This revolutionary change has, of necessity, fundamentally altered many of our business concepts, practices, and procedures. Design for manufacturing is becoming the rule among sophisticated manufacturers. It is also the name that has been applied to the good engineering and design principles that govern manufacturing in this era of fast, tireless, but nevertheless limited production equipment. Manufacturers now realize that when their engineers rethink component design with automation in mind, they will reduce the manufacturing costs of their products, and improve the effectiveness of their equipment.

Manufacturers today are realizing that the battleground for world-class cost competitiveness is indirect, sometimes highly nonvalue-added expense, best attacked at the early design stage. The front end of the development schedule can actually be beneficial by spurring clearer, quicker, and more accurate thinking. Those who get products out quickly do it by building and testing models relentlessly. By taking several small steps, a company can advance its market position faster than by making one giant technological leap. In order to help their customers, some manufacturers are using design for manufacture and assembly techniques.

REFERENCES

1. **Childs, J. J. (1984):** Principles of Numerical Control. Industrial Press, 3rd Ed., New York.

2. **Ealey, L. A. (1989):** Quality by Design: Taguchi Methods in U.S. Industry. American Supplier Institute, Inc., Dearborn, MI.

3. **Nwosu, H.U. (1991):** Design/Development Engineering Projects on Designing For Automation and Assembly for Computer Hard Disk Drives. Seagate Technology, Inc., Oklahoma City, Oklahoma.

4. **Ransky, P.G. (1992):** Computer Networks for World Class CIM Systems. CIM ware, U.K.

5. **Ransky, P.G. (1990):** Manufacturing Database Management and Knowledge Based Expert Systems. CIM ware U.K.

6. **Stark, J. (1989):** Manufacturing Automation and Integration. Auerbach **Scherkenbach, W.W. (1986):** The Deming Route to Quality and Productivity. CEE Press Books, New York.

7. **Tompkins, J. A. (1989):** Winning Manufacturing: The How-To Book of successful manufacturing. Industrial Engineering & Management Press, Norcross, GA.

8. **Wright, R. (1996):** Systems Thinking: A Guide to Managing in a MI.