MANAGING TECHNOLOGY

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ABSTRACT

What changes constantly, is optimized with difficulty, and cannot be bought or sold; yet without it, making web based products is impossible? The answer: Web Handling Technology. Ten years ago 3M established a Web Handling Research Group to convert the art of web handling into a science. Since then, we have determined many of the engineering principles governing the control of flexible media, established connections with several research centers, and published papers. However, subsequent to our success in gaining understanding, we have had to face the additional challenge of translating our knowledge into a form that will be useful in equipment design and production. This presentation will concentrate on the tools and processes we have used to effect this translation.

DEFINITION

The process of technology introduction is similar to that of equipment installation, and can be managed: hence the title, Managing Technology. Since it is possible to confuse Technology Management with Project or Technical Management, distinguishing between the two is essential. Technical Management means supervising the procedure that provides process machinery to manufacturing, while Technology Management means supervising the procedure that provides the appropriate technology (process understanding) incorporated into the machinery design. The former provides the steel; the latter the operating principles.

JUSTIFICATION

Managing technology begins with process understanding, which is both complex and expensive. According to an NSF survey cited by Bisio [1], industry spends a lot of money on process R&D. His research indicates that money spent on development of new or improved products and processes accounts for most of industrial R&D expenditure, and he calculates that the rate of return is between fifteen and fifty-five percent.

Considering this large investment of capital, a company needs to make sure that money spent on process understanding contributes to, rather than detracts from, profitability. The profitability question can be quickly answered. Two years ago, at the Third International Web Handling Conference, Dr. Hakial [2] presented conclusive evidence that the application of first principles process understanding is a profitable endeavor. Simply put, what you learn at an academic conference, or in a classroom, can contribute to your company's "bottom line".

Given profitability, then, the next question becomes: "Should we spend our own R&D money on process understanding, or can we buy it from our suppliers?" The answers are: "No, we cannot buy it, because suppliers are in business to design and sell machinery; and therefore, Yes, we ourselves must invest in process understanding." Clearly, the more experienced suppliers have gained a basic knowledge of how webs are transported over rollers and rewound, but since these suppliers do not have access to webs for experimenting and proving concepts, they must rely on limited feedback from customers. I remember visiting a major web handling equipment manufacturer who had managed to collect two whole stock rolls of 2 mil polyester film. The chief engineer was overjoyed that he finally had some unassigned material he could use for developing a new winding clutch. As he was talking, I thought of the large room full of various stock rolls that we had stored in our lab, just for experimentation. It is obviously the film-based manufacturer, and not the web-handling equipment supplier, who has access to the webs needed to develop process understanding.

CHOOSING THE RIGHT APPROACH TO PROCESS ENGINEERING

There are two distinct approaches for introducing web handling equipment to manufacturing; One we will call "Trial and Error" and the other "Process Understanding". The difference is that, while trial and error involves applying rational thought in continual experimentation, Process Understanding involves the application of first principle.

Trial and Error is the most common approach for developing and introducing process machinery. In developing processes, although we may occasionally employ experienced, rational thinking based upon knowledge of physics, mostly we just try them to see if they work. This is not to say that Trial and Error depends upon a poor philosophy. To justify its benefits, one only need consider a great inventor like Thomas Edison, who employed Trial and Error more than most of us. For low-risk programs, making small, evolutionary changes in an existing process is suitable to the Trial and Error approach. However, by its very nature, Trial and Error implies a time and technology risk that is not acceptable in this age of fast product introduction and short product life. An entrepreneur wanting to make a quantum jump, falls short using Trial and Error.

On the other hand, the first principles approach associated with Process Understanding provides the necessary predictability to avoid Trial and Error problems. To illustrate the difference between these two opposite methods, imagine each to be represented by a path winding over a landscape of rising hills. Both paths require that a hiker exert energy while climbing; the steeper the path, the more energy required. The

Process Understanding path has a very steep portion at the start, due to the initial R&D, while the Trial and Error path gets steeper near the end, due to unforeseen startup problems. Viewed at the outset, Trial and Error appears easier. However, once the startup problems commence, Trial and Error shows its weakness, especially if the program is trying to take a giant step in manufacturing or product design.

Many times, we have heard the statement: "I wish we had known more before we started." Recently, an engineer with no web handling experience was asked to install a machine to make a new product. Since this product was unique, the risks inherent in entrepreneurship and innovation were a given. The task was to install a machine that provided a radically different step in web handling technology. Unfortunately, none of the equipment suppliers was familiar with web handling equipment and they were therefore unable to give the engineer any advice. Neither did he consult the corporate web handling researchers, so there was no web handling process understanding involved in creating an innovative web line. After two successive delays in product introduction, management finally called in someone versed in web handling principles, who replaced the ineffective machine with one that worked. The project was ultimately successful, but at the considerable cost of first purchasing the wrong equipment, and then delaying product introduction. It goes without saying that the money wasted on a useless machine might far better have been spent on research.

CHOOSING THE RIGHT PHILOSOPHY

The French economist J.B. Say, ca. 1800, wrote: "The entrepreneur shifts economic resources out of an area of lower and into an area of higher productivity and greater yield."[3] This definition propounds the economic theory that change is the norm– that doing things in a different (unique) manner is more profitable than simply doing the same old things better.

It appears, then, that the profitability derived from process understanding is in the hands of the entrepreneur; and furthermore, that when processes are innovative, they are also likely to be profitable. For example, it is not entrepreneurship to double capacity simply by adding a new coater. Rather, an entrepreneur might suggest a new coating/drying method which would speed up the existing machine, while simultaneously improving quality and yield. Adding the coater would be a low-risk technical project, while upgrading an existing line for new coating and drying methods would involve higher risk.

In the foregoing case of installing the wrong machine, the project engineer and suppliers were trying their best to succeed, but were unfortunately viewing the project from the wrong perspective. The product had been developed by a discrete, laboratory process involving hand laminating individual lengths of web. Moving to a web line changed this discrete process to a continuous one, and introduced new secondary processes such as unwinds, tension control devices, slitters, and sheeters. I believe their problem was in not viewing web handling as the foundation process into which the product making processes were inserted. The innovation was not in laminating a new product, but in assembling a web line to handle the webs during lamination and sheeting. The move from discrete to continuous web handling produced the challenge and problems.

This kind of change-producing entrepreneurial innovation requires a willingness to take quantum jumps in technology. Unfortunately, as Druker claims, even though companies fund research, the corporate perception of entrepreneurship is that of enormous and expensive risk. Since Management usually favors gradual, evolutionary change, with its predictability and lower risk, this is where the two methods clash. I remember sitting in a meeting of engineers, who were all about the same age, and had the same general background. All of us would probably have communicated very well on any other topic, but because half of us were 'technical' and half 'management', we found it impossible to reach a consensus on the subject of risk. The technical side saw risk as a necessary step to success, while the management saw it as a possible cause of failure.

Thomas Khun, in his book The Structure of Scientific Revolutions,[4] maintains that it takes about thirty years before a new theory becomes, in his terms, a *paradigm*. In the previous example, management – with its process evolution theory – and technology – with its quantum leap theory– are operating under two different paradigms. Possibly, it will not take thirty years to merge the best of both; however, I see few signs of it happening any time soon. Obviously, those industries that manage to allow entrepreneurs the freedom to develop innovative process changes will have a head start on everyone else.

IMPLEMENTING PROCESS UNDERSTANDING

Before implementation, it is important to determine if Process Understanding is really needed to replace Trial and Error. Questions specific to product manufacturing must be asked, such as: Are the first principle relationships already understood? Is a significant step in process design required? Is time a factor? Remember that Trial and Error is not a bad philosophy; merely a limited one. The key to success for project and design engineers is an ability to provide innovative answers to technical questions. To do this, they need a working knowledge of first principles, but unfortunately, both their training and experience have been largely in Trial and Error.

Implementing process understanding requires transferring first principle knowledge out of the province of the researcher, and into that of both Manufacturing and Engineering. In manufacturing, you train process engineers to solve problems; in Engineering, you train project and design engineers to avoid problems in current and future processes. Without this knowledge transfer, the researcher winds up wearing all the engineering hats – from designer to problem-solver – and work gets done with less efficiency. For example, I was once called to a plant that had changed to a thinner web, thereby creating a wrinkle problem, which I determined could be easily solved by a simple change in web path. However, because the process engineer had no understanding of basic principles, the line again malfunctioned, and I was called back to address the same problem. I found that the line had been returned to the original web path, and a special roller had been added, but now neither the thick nor the thin film would run without wrinkles. Their reason for changing back had been the fear that the new web path would have a detrimental effect on thicker web coatings. Since both process path and coating conditions had been optimized initially by statistical processes (Trial and Error), ignorance of first principles knowledge created a fear of making any permanent change, and this in turn resulted in additional trial and error to find a new web condition for both film types. Here the question was not one of intelligence, experience or ability – it was simply lack of understanding. The necessary knowledge existed in the company, but, unfortunately, not in the process engineer! If it had, it could have been used to define, prevent or solve this kind of problem. I would then have been called in primarily to consult, and ownership of the solution would have remained with the process engineer.

Since Engineering has two distinct parts; one concerned with pure knowledge and the other with practical application, there are two paths to becoming an engineer. In the first, the pragmatic road of on-the-job training, the student may not learn many basic principles, but will become expert at utilizing common sense and experience in machinery design. On the second path, formal training introduces one to basic engineering principles before moving into practical application. However, since this application phase is where most engineers spend their careers, the basics learned early on are often replaced by Trial and Error. The result, then, is that both paths ultimately produce dependence upon trial and error methods rather than encouraging predictions based on first principles engineering. If we want to be truly innovative, this traditional way of operating must be replaced by a reliance on first principles.

OVERCOMING RESISTANCE

Resistance to applying first principles may manifest itself in any numbers of alternative suggestions, digressions, and impediments, all stemming, in my view, from observing web handling in the light of opposing paradigms. The dictionary defines a paradigm as an acceptable model or pattern. Kuhn [4] determines whether a scientific method is a paradigm by demanding that it adhere to two characteristics or patterns. The achievements derived from applying a method must: First, "be sufficiently unprecedented to attract an enduring group of adherents"; and second, "sufficiently open ended to leave all sorts of problems to resolve". It is not difficult to see that people who share paradigms are committed to the same rules and standards. Therefore, anyone who adheres to a method for applying web handling technology that is different from yours will offer at least some resistance.

For example, showing the relationship between process understanding and profitability is often difficult. I maintain that the key is demonstrating web handling not only as a process, but as the foundation process for manufacturing web based products. Unfortunately, web handling, like most other enabling processes, is usually invoked only when there are difficulties, creating two conflicting paradigms: one viewing web handling as a process, and the other as a problem. I once received a call from an engineer, complaining about web handling problems that surfaced while working on a laboratory scale-up for a new product. When I asked to have the problem described, there was a long silence, and then: "Well, we have a number of issues – but, but –." To finish the sentence, I suggested: "You have web handling, right?" to which there was an immediate answer of "Yes! We have lots of web handling!"

Another form of resistance is concentrating on the product making process, to the exclusion of web handling: for example, seeing a coating line as merely the coating heads, rather than as a web line with a coater in it. We have discovered it quite innovative to suggest first constructing a web line to meet the product manufacturing specifications, and then inserting the manufacturing processes into it. When this is not done, strange web lines abound. Cases in point are: a laboratory scale-up attempt which had idler rollers mounted on ring stands normally used to support chemical apparatus; or unwinds and rewinds "C" clamped to the legs of a coating station. Is it any wonder that there were wrinkle problems? Recently I was involved in helping to scale-up a decidedly innovative process for introduction into manufacturing. The program's process engineer was insistent that we run the experimental line at very low tensions. When I asked why, I was told that it was because the factory line ran that way due to a poor unwind. There, the best running condition was with the brake off, and the web "free wheeling" through the process. This project engineer had not considered that it might be problematical to inserting a new innovative process into an old and defective web line, or that it might compromise the success of any new, innovative process. To him, the web line just did not matter!

One of the biggest obstacles to applying first principles is the difficulty of convincing management that it is profitable. Since much of management consists of engineers whose success has been in Trial and Error methods, they often view up-front risks as more threatening and costly than a program based on best guess and experience.

Another impediment to process understanding is management's difficulty in seeing it as the best means to optimize existing products and provide new ones. For example, one of my former bosses recounted his problems with trying to scale up a product, when, to gain the requisite process understanding, he did some of his development work on factory production machines. The plant manager saw no need to understand anything: his advice was to "Run it the way you did the last time you had a success, and stop wasting valuable manufacturing time."

TECHNOLOGY TRANSFER

The foregoing sections clearly demonstrate that getting the most profitability from web handling requires choosing a process understanding approach over trial and error, and embracing a philosophy of innovation, which looks for different, rather than simply improved ways of doing things. We have seen web handling not only as a process, but as the foundation process for all others – As goes the web, so goes the coating, drying, and slitting. We have seen that expecting researchers to be the primary agents for transferring web handling principles to manufacturing and engineering is not practical, and finally, we have seen that resistance to suggesting innovative changes is not only possible, but probable. There is, however, reason to hope that colleagues who believe in process understanding do exist. The questions then become who and where are they, and how do we develop a working relationship with them? Or, to be even more basic, can we train people to become web handling experts, and thereby develop our own networks?

Through discussions at numerous corporate levels and in different engineering environments within 3M, I have discovered a wide range of opinion on risk-taking, causing me to conclude that in small, relatively autonomous organizations, where management structures are close to the process, there is more willingness to risk. Some of these organizations are factories where process development is encouraged, even when it involves applying high risk, and seemingly bizarre concepts. Other organizations have designers and engineers, unsatisfied with current technology limitations, taking the time to learn new skills in order to explore process alternatives. Clearly, these groups and the people in them are the most likely places to find fertile ground for the growth of entrepreneurship and innovation. Once these people are identified, and relationships between research and application have been established, there is an open path for transferring research knowledge into a form that is useable by both engineering and manufacturing.

The next questions involve translating research results into a usable form, and then getting them into these receptive organizations. Even more difficult is the problem of kick-starting those organizations that need the process understanding, but are either not aware of their deficiency, or are unwilling to acknowledge it. In order to realize the full benefits of applying process understanding to web handling, we must establish a Technical Transfer function, not only to get research knowledge into the hands of those who already want it, but to convince others that they need it.

Technical Transfer can be accomplished in several ways. The most common is in the form of books, technical papers, or conference proceedings. This source is *the sine qua non* for sharing research results, but interpretation is often difficult. Consider a factory's process engineer with daily responsibilities for keeping product flowing, who has a high tension problem resulting in wound roll deformations. Now, give this engineer a technical paper analyzing stresses in a wound roll. First, the engineer has to understand what is written, which requires a mathematics background. This usually eliminates process engineers who have come up through the "School of Hard Knocks". Next, he or she must be able to extrapolate that the deformation problems are stress related, and finally, to convert what was written into a computational form that includes the possibility for adding measurements and controls to the existing process. All this must be done simultaneously with keeping the process running! I have know it to work, but only on rare occasions. In light of these difficulties, I believe the written report to be an inefficient method for Technical Transfer outside of the academic community. Although putting a distribution list on a report or conference book and sending it around the company seems to be the easiest way to disseminate technical information, I doubt its efficiency.

A higher, but more effective level of effort involves organizing company web handling courses and seminars. In this case there is an interpreter to help relate process understanding to problems. Still, this difficulty remains: when the conference is over, who is going to apply the principles? Conferences and classes, I have found, are good for consciousness-raising and some process definition, but provide no time to get into problem solving. However, relationships are established that help the engineer to solve problems in a factory or with defining equipment specifications, where the researcher is now in the role of a consultant rather than that of a pair of smart hands, and can therefore take part in problem definition rather than simply being asked to solve a problem already defined. As long as the researcher is working with someone who has a background in the process understanding, and is willing to learn, some Technical Transfer will remain in the factory or engineering organization after the researcher is gone.

The third, and most efficient method for Technical Transfer is that of training engineers to become web handling experts. I believe that to attain the maximum profitability, engineers with expert web handling knowledge must be in close contact with projects. Obviously, the people closest to production – the manufacturing process and maintenance engineers, located right in the factories, – have the most to gain from understanding web handling, while in an engineering organization, these key people are the design and project engineers. One way to get expertise into critical organizations is to transfer people from research to manufacturing. This is especially helpful if the organization does not yet see the benefits of applying web handling understanding, nor has it developed Technical Transfer relationships. However, because research engineers unfortunately do not usually like the day-to-day problems associated with manufacturing, it is often easier to make personnel transfers to project or design engineering functions. Therefore, a more practical alternative to personnel transfer is training people from receptive organizations to become web handling experts. In order to do this, there needs to be an engineer who perceives a career advantage in applying process understanding, and this engineer must have a supportive supervisor, who believes that applying process understanding is profitable. A third condition is also advantageous: If there is already a benefits of applying process understanding to web handling, we must establish a Technical Transfer function, not only to get research knowledge into the hands of those who already want it, but to convince others that they need it.

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To illustrate: one of our manufacturing process engineers had reached expert level over several years of being mentored by researchers. Since then, he has completed web handling programs that took as long as four years to accomplish, and resulted in considerable cost savings. In addition, the benefits have gone beyond problem solving and waste control. By being constantly on the job, he has been able to use his web handling expertise in the decision-making process for expediting the flow of product through the plant. As a result, applying web handling process understanding has made it possible to run multiple products on one line, encouraging business expansion programs. It is difficult to believe that a detached, problem-solving researcher could carry programs requiring that much on-the-spot attention.

MENTORING

A Mentor is defined as "A trusted counselor or guide". I define the training of experts as Mentoring, choosing this description over others such as training, teaching, and Master-apprenticing, because it best describes the relationship between the trainer and the trainee. Establishing a mentoring process varies from company to company, but there are some features likely to be common to all.

First, the mentor must be a researcher, or at least someone who is familiar with web handling first principles understanding, and the person mentored must be free to spend time away from normal activities in order to learn web handling technology.

Second, the mentoring process must have both formal training and on-the-job application. When you are teaching problem-solving, there is nothing like having real problems to solve!

Third, the mentoring program must define some mutually agreeable responsibility accepted by both the mentor and the engineer. For example, the mentor places a priority on giving the engineer attention, and the engineer agrees to devote a defined amount of time learning basic principles. Whatever the program, it requires that the mentor and engineer be able to spend enough time together to develop a good professional relationship. Obviously, to accomplish this, management support is crucial: a supervisor must believe that it is worthwhile to have the engineer a spending significant amounts of time on activities that cannot be directly linked to factory or engineering concerns.

CONCLUSION

Profits are made from choosing and optimizing the correct product-making process. Because web handling is a process that is integral to manufacturing products from continuous flexible media, applying process understanding is profitable. Any method that gets fundamental understanding of web handling into a company is helpful, although the level of profitability is determined by how process understanding is applied. This paper has recommended a program for attaining profitability based on dissemination of technology among select organizations within the company, rather than centralizing it into a corporate research function. Web handling is based on knowledge, not on machinery, and therefore cannot be delivered to a factory as a turn-key operation. The processes that govern web handling also govern product manufacturing process such as coating, drying, and slitting. Therefore, the web handling foundation process must be robust enough to accommodate optimization of these critical processes, by such modifications as changing tensions, roller placement, and the introduction of additional processes. In the best of all possible web handling worlds, companies will have engineers trained in process understanding directly responsible for processes and product manufacturing, close to the process, able to predict optimization requirements, and on the spot for problem solving and machine modifications. May that utopian condition soon come!

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