1986—ASQC QUALITY CONGRESS TRANSACTION—ANAHEIM

STATISTICAL PROCESS CONTROL (SPC) AND AUTOMATION

Hans J. Bajaria
President
Multiface, Inc.
Dearborn Heights, MI 48127

ABSTRACT

Among many viable approaches to improve Quality and Productivity of the manufacturing processes in automotive related industries, the recent thrust continues to be implementation of Statistical Process Control (SPC) and Process Automation. These two items are consuming a significant portion of the automotive industry investment funds. For such an investment to pay off in a timely manner, the inherent ability of process automation to provide a higher level of quality must be integrated with SPC.

In this paper we examine different schemes for integrating SPC and automation. The various elements of the schemes considered are: Forms of Data Collection, Types of Data Analysis and Plotting, Types of Signals for Detecting Incipient Troubles, Discovery of Associated Disturbing Causes and Correction of those Causes. For this integration to succeed, an understanding of both functional and process control automation and their balance is also needed. We discuss the fundamental differences between these two forms of automation. Further we elaborate on the distinction between the deterministic and probabilistic process control automation and their balancing criteria. To avoid a disproportionate distribution of the invested funds it is necessary to optimize process performance with respect to three forms of automation: functional automation; deterministic process control automation; and probabilistic process control automation.

This paper provides guidance to facilitate automation of manufacturing processes or to improve the efficiency and yield of existing automated processes.

INTRODUCTION

Automation has the potential to improve the productivity of manufacturing processes and simultaneously to increase the quality of their output. In order to tap the potential benefits of process automation, various time consuming functional elements and various causes that contribute to unacceptable process performance must be understood and controlled.

Productivity improvement is based on the speed with which automated process can operate as compared with manual processes. When automation offers speed, it can be labeled as FUNCTIONAL AUTOMATION. On the other hand, the quality potential of process automation is based on the precision with which an automated process can repeat as compared with human hands. Therefore, when the automation is applied to improve the consistency of process output, it can be labeled as PROCESS CONTROL AUTOMATION. Figure 1 depicts the difference between FUNCTIONAL AUTOMATION and PROCESS CONTROL AUTOMATION.

The primary focus of functional automation is to increase the speed of the process whereas the primary focus of process control automation is to improve the consistency of process output. Regardless of where the focus is intended to be directed, process automation always results in significantly greater speed than can be achieved by human hands. In this paper, the emphasis is placed on process control automation.

It is also important to understand the role of Statistical Process Control (SPC) as it relates to process control automation. Use of SPC to monitor any process output will indicate the instabilities as well as out-of-control conditions in the order that they occur. As the causes for such conditions are discovered, corresponding corrective actions need to be found and taken to restore the process to its natural state. If such conditions occur on a consistent basis, there must be standard operating procedures developed to take care of them. These procedures then can be automated so that their execution will not depend on human judgement or motivation. This scenerio forms the close connection between automated process controls and SPC. Statistical control charts can be considered to provide the strategic guidance necessary to convert those standard operating procedures into automated procedures in the order that they create disturbances to the process output. The use of automation for process control generally requires greater capital investment than conventional ways of handling the same issues. If the investment is required to yield a timely payoff, it must address those hardware improvements that bring quicker rewards. The use of SPC in determining what aspects of process controls need to be automated first, almost guarantees a handsome return on investment.

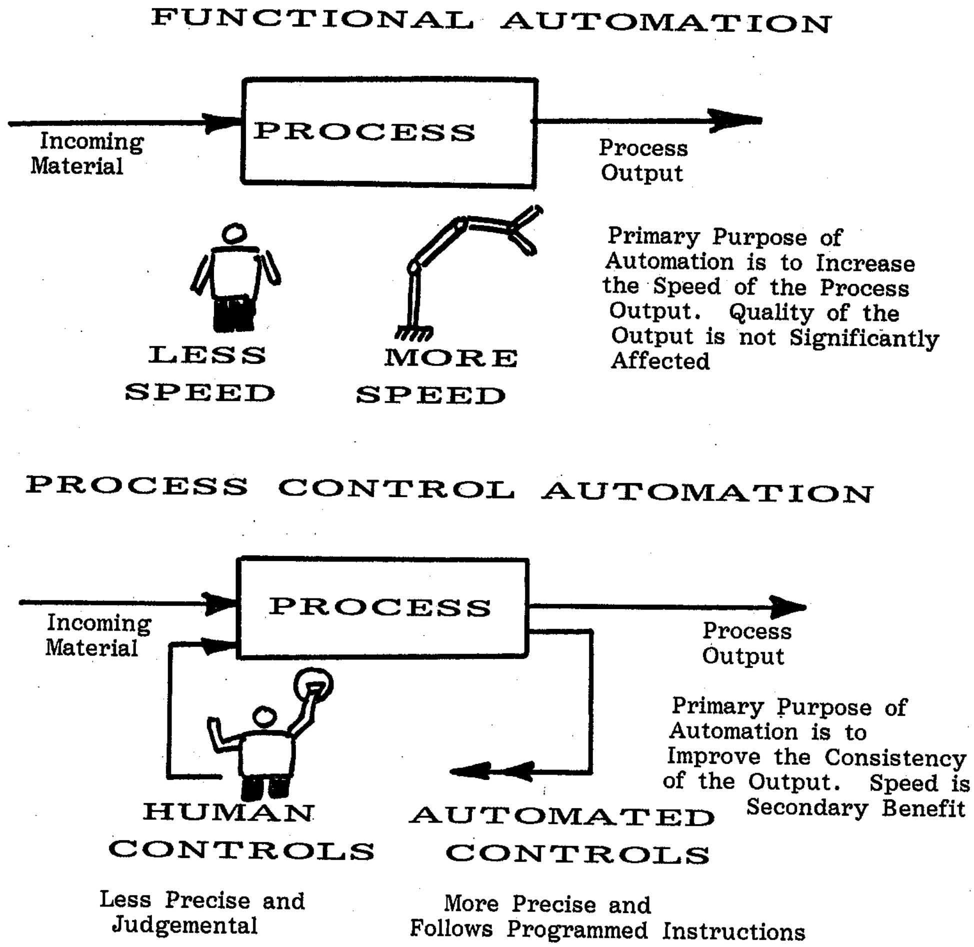

Figure 1 - Difference Between Functional Automation and Process Control Automation

Basically process control issues can be broken down in two categories: (1) Process control against previously known process disturbances and (2) Process control against previously unknown process disturbances.

(1) PROCESS CONTROL AGAINST PREVIOUSLY KNOWN DISTURBANCES

Figure 2 shows the three elements of process control which can play a role in perturbing the condition of a process output, namely, (A) Human Hands, (B) Standard Operating Procedures (SOPs), and (C) Process Parameters. It is necessary to control the known relationship between each one of the process control elements and the process output. That means, if efforts are not made to maintain these relationships, the process is likely to loose its state of statistical control. These are known as Deterministic Controls.

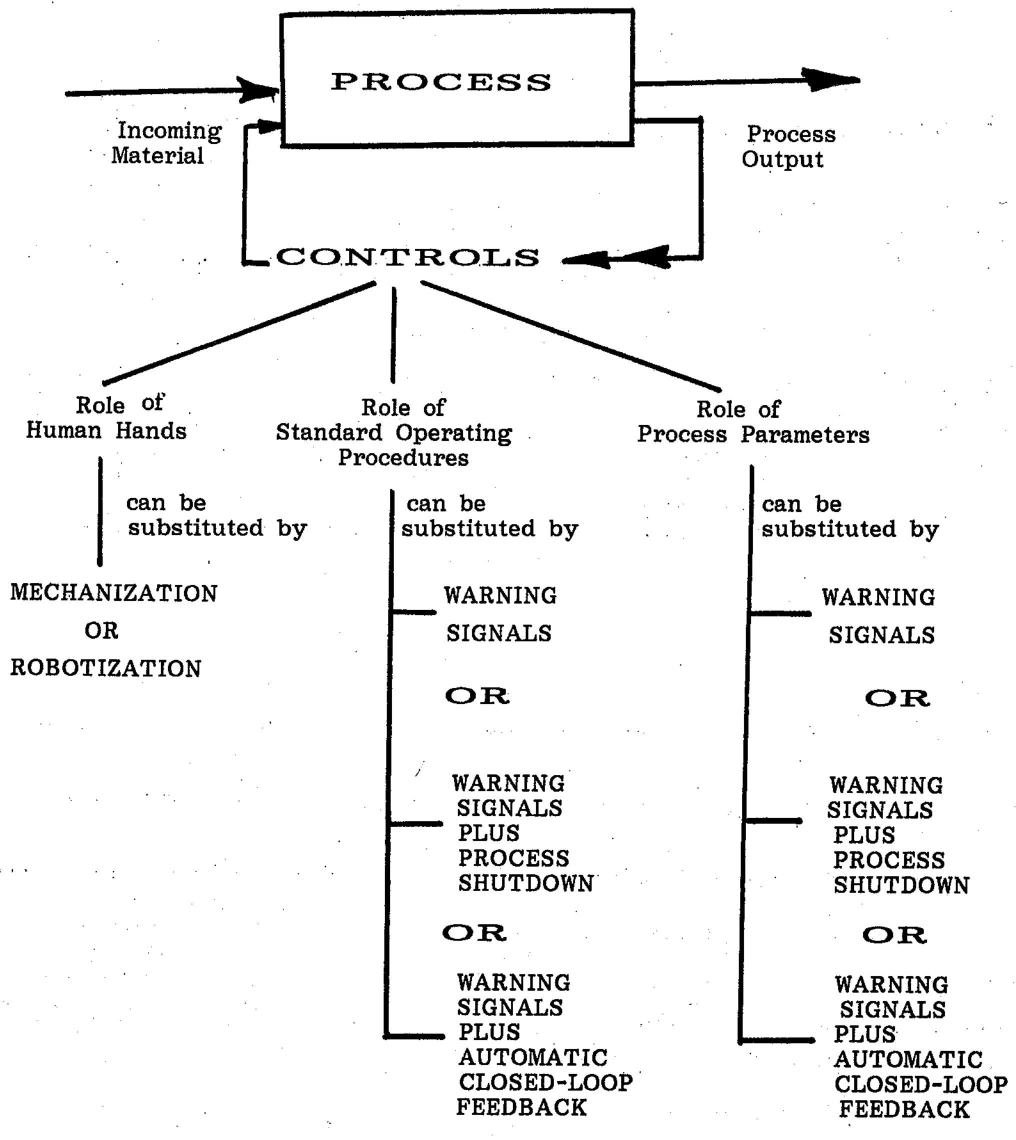

Figure 2 - Deterministic Process Controls and Automation

(A) Role of Human Hands - It is a well-established fact that automated equipment will repeat better than human hands. Suppose that a manual process is used to produce the product and SPC is used to track its output. With sincere use of SPC by operating personnel, it would be possible to keep the process in a state of statistical control. However, if one examines the manual process capability, it will certainly be wider than that which can be achieved by the use of mechanization or robotization. Therefore, if automation is used instead of human hands, not only can the process be maintained in a state of statistical control but its capability will be much improved (i.e. 6 sigma will be narrower).

There are two points to remember as to how automating the role of human hands and SPC are tied together.

a. SPC can be used to ascertain whether the process is going out of control as a result of variation in manual handling or that the process has an unacceptably wide spread. Automating the process can solve both problems and improve the process significantly. Here SPC can act as a thermometer indicating type and degree of sickness, whereas automation can act as medication for removing that sickness.

b. If there are some products which a competitor makes using automated machinery, he clearly has the advantage with respect to process repeatability and efficiency of production. SPC of the manual process will not compete with such a scenerio eventhough it can deliver the best that the manual process has to offer. The use of SPC cannot be considered to be strategic under this set of circumstances.

(B) Role of Standard Operating Procedures - It is a well-accepted fact that SOPs are very hard to follow on a continuous basis if they depend on humans for their execution. For example, let us say that the SOP calls for a tool change after every 300 parts are processed. This procedure may or may not be executed depending on the knowledge and motivation of the operating personnel. There are numerous examples of such violations throughout the automotive related industries. Implementation of SPC would provide conclusive proof whether such is the case or not. Obviously, lack of discipline in following the known procedures results in poor quality. Using SPC to discover such violations is certainly not very effective use of SPC. Use of SPC will assist us to discover the unknown disturbances which are otherwise difficult to determine and not to prove the fact that the procedures are not followed. If the SOPs are automated then there would not be any need for human judgement in executing the SOPs. The automated SOPs can provide signals or signals plus automatic halt in the process or signals plus automatic correction of the disturbing causes. Of course, the automation is not completely foolproof either, but several orders of magnitude improvement can be expected.

Again, there are two points to remember as to how automating SOPs and SPC are tied together.

a. SPC will only reveal whether standard operating procedures are followed or not. The automation of SOPs will assure that they are followed.
b. Discovering violations of SOPs by using SPC is not a very effective use of that tool. Why use SPC to discover more things to do (more SOPs) when we know we are not doing the things we should be doing now (i.e. not executing existing SOPs).

(C) Role of Process parameters - There are many process parameters (e.g., temperature, pressure, feed, speed, cure time, loading rate, etc.) that affect the process output. These parameters need to be controlled within well-defined ranges in order to obtain acceptable process output. It is not always possible to keep these process variables within prescribed ranges. There are basically two reasons for this difficulty: equipment limitations; and over-eager but unskilled problem solvers who over-control the process. Use of SPC can point which case applies. However, if the process is automated, we can obtain a signal when such violation occurs or obtain a signal and shut down the process; or we can obtain closed-loop feedback to fix the disturbing signals.

Another important point to note which ties the automating process parameters ranges and SPC is that the use of SPC can reveal violations to prescribed process parameter ranges whereas automation can provide real time signals and closed-loop feed back for their correction when they are violated.

(2) PROCESS CONTROL AGAINST PREVIOUSLY UNKNOWN DISTURBANCES

Manufacturing operations are always prone to problems. Furthermore, the causes of these problems are often difficult to predict in advance. Causes which can be predicted are generally handled by Standard Operating Procedures, Prescribed Process Parameters Ranges, and Well-defined Training Elements for operating personnel. As discussed earlier, use of SPC will reveal whether the discipline exist to control these known relationships and the use of automation will almost guarantee that any disturbances to these relationships which can put the process statistically out-of-control will be better controlled. What about unknown causes that can disturb the state of control for any process? SPC is the only tool capable of providing true signals against disturbances of unknown origin. The execution of SPC requires that the process output (product characteristics) signals be monitored authentically and on real time basis on appropriate statistical control charts and that actions be taken based on the interpretation of these charts.

In the past, automotive companies have utilized control charts only on a selective basis rather than a rule. In fact, their focus has been on product specifications rather than statistical control limits. Corrective actions are taken only when the parts are out-of-specification range. Use of SPC requires that actions be taken when the parts are out of statistical control limits. Similarities between two approaches are that in both instances the part conditions are examined but the differences come in as to when the actions are initiated. This fundamental difference is very difficult to rectify in the automotive production environment.

A major difficulty in implementing SPC is that the workforce in automotive related companies is habituated to think specification lines and not control lines. Though the control chart concept can be illustrated with simple mathematics in the classroom, it is very difficult to execute the idea on the production floor due to "conventional thinking habits". Furthermore, decisions made using control lines, in some instances, coincide those that may be made using specification lines (or by the good old instincts of the experienced operators). This creates argument in favor of status quo. One can state that decisions based on control limits will always be correct, whereas decisions based on specifications limits will sometimes be correct and sometimes be incorrect. Regardless, if one were to use control limits as the basis for decision making for process corrective actions against unknown causes, then several steps need to be understood for proper execution of SPC. These are:

(a) Measure process output (product characteristics of interest)
(b) Record output as raw data
(c) Plot authentic summary of these data on the appropriate control charts on a real time basis
(d) Interpret control charts as each additional point is added to the control charts. For complicated patterns showing up on the control charts, this may take considerable analysis time.
(e) Determine corrective action.
(f) Take corrective action.

In present day automotive production environment, if operating personnel were to execute SPC, they must be educated in SPC philosophy, and SPC methods. In addition, they must be trained in the execution of these methods in their production environment. This is a very sore issue not only for the automotive related companies but for any industry, since the majority of workforce coming from a diverse background is neither educated nor trained to think like this. Additionally, an organization issue that may hamper the SPC effort, is performance measurement by time standards. The makeup of standard time, in general, does not account for the time it may take to execute SPC steps effectively. Of course, there are some exceptions where an operator has idle time between operations. SPC efforts can be "squeezed into" that idle time. This may or may not be welcomed by the operator who may perceive this as merely an additional burden. Also, very few, if any organizations who claim to have implemented SPC have modified their standards. If one critically examines SPC implementation success claims made by several companies, there are bound to be some cases of exaggerations, since effective SPC implementation is usually not possible without modification of some of the time standards. Use of process control automation may provide some resolution for these difficulties.

Figure 3 indicates several stages of automation that are possible. This is also known as Probabilistic Controls in the sense that process output signals are statistically monitored and their interpretation (to determine the disturbing causes) requires the use of statistical tools.

Stage a - Process output is measured manually (i.e., the operator makes the measurement). The measurement device can be directly plugged into the data storing device which can then be used to generate appropriate control charts. This stage has the disadvantage that the operator still has to handle the measuring device.

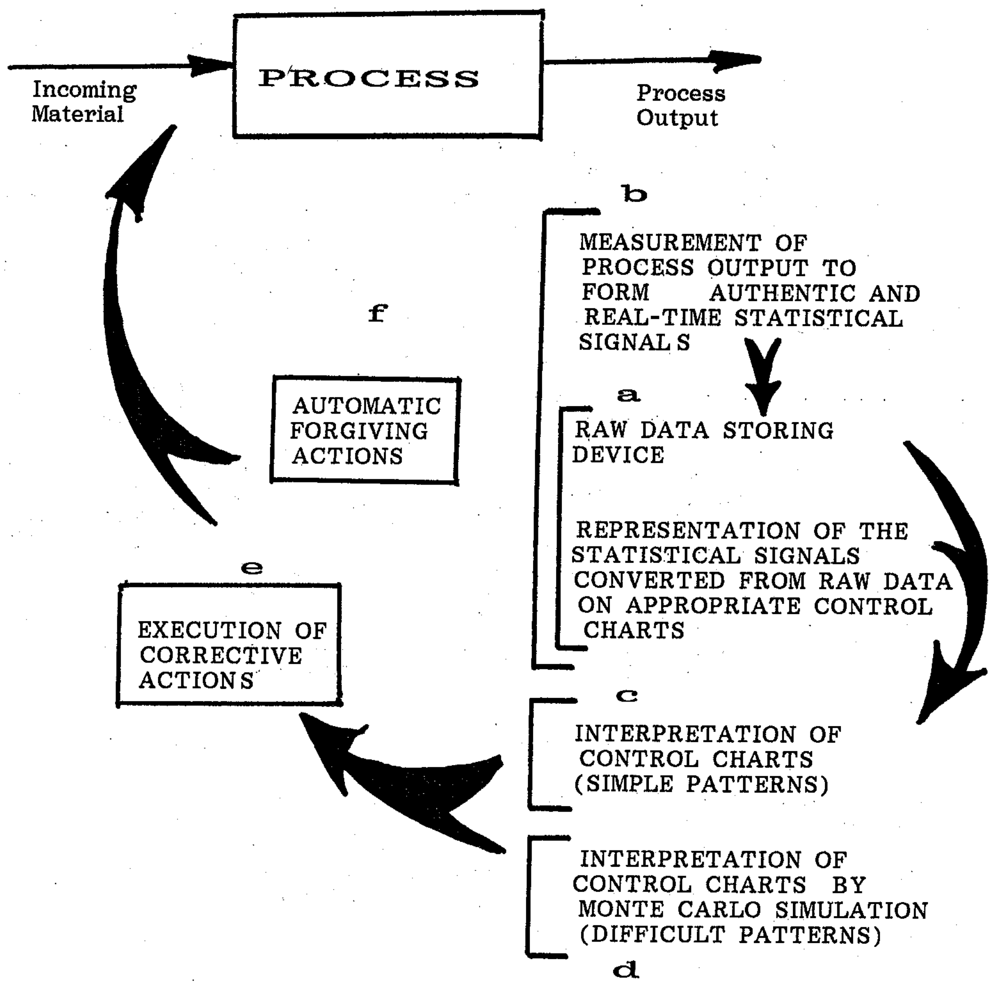

Figure 3 - Probabilistic Process Controls and Automation

Stage b - In this stage, the gage is part of the process. Process output is automatically measured and the desired statistical signal is stored in the data storing device. This data storing device itself can be capable of generating an appropriate chart or it can be plugged into a computer to do the same. This can cut down several manual steps that might be required in measuring, summarizing and plotting. Interpretation of the pattern is still based the skill of the chart reader, with the exception that an out-of-control condition can be signaled.

The disadvantage of this method is that the cost of gage (which is now an inherent part of the process) may be prohibitive. Also, it may not be possible to buy off-the-shelf measurement technology to measure all of the process output characteristics of interest.

Stage c - The question of interpretation has always bothered SPC enthusiastists. In fact, insurmountable difficulties in reading the charts and determining the corresponding hardware actions has resulted in apathy toward implementing SPC. What is required to interpret the charts is to be able to sincerely jot down the process changes as soon as they occur as well as track the condition of some top suspect variables along with each plotted point. Many failures in reading charts are associated with the incompleteness of such records. Here automation can help out again. One can build the idea of tracking potential suspects along with plotted signals on the control charts. Also one can build the algorithm into the computer to automatically signal the condition when the varying pattern on the control charts begins to coincide with the varying pattern of the suspects. The algorithm should be able to examine not only the patterns followed by the individual suspects but also those that are folllowed by all possible combinations of suspects. This automation in control chart interpretation can reduce the tedious task of relating output patterns with the suspect patterns to determine the corresponding hardware actions.

Stage d - Even after these stage c efforts are made toward interpretation, it is still possible that the control charts are difficult to interpret. Here control chart interpretation can be advanced to the next level of sophistication. The analyst should be able to ask some "what if" questions with the help of computer simulation methods. Monte Carlo simulation methods are quite powerful in executing this idea. Lets examine the essence of the Monte Carlo simulation procedure. The analyst first chooses (guesses) the type and degree of perturbation in the suspected process variables. Then he describes this perturbation in the form of a mathematical model. He then uses the Monte Carlo simulation to generate the control charts that reflect this scenerio. He then compares the simulated control charts with the actual control charts. If the simulation generated based on one or more of his guesses in fact duplicates the actual (observed) control chart pattern, the analyst can then explain the observations. This is the ultimate that can be achieved with respect to automation of control chart interpretation.

Stage e - One can now step into the arena of hardware action to correct the process. After having interpreted the control charts, SPC has provided all that it can deliver. Corrective action still needs to be taken. Here again automation can help. Process corrective actions can be of two types: turnable knobs to alter process parameters such as temperature, pressure, cure time, speed, feed, loading rate, etc; and unturnable knobs to alter process parameters such as material variation, worn tool, fatigued operator, etc. Automation can maneuver the turnable knobs to restore the process to its natural state or it can flash a message indicating the most probable unturnable knobs that are responsible for the patterns observed on the control charts.

Stage f - The ultimate in automation is to be able to utilize the forgiving nature of some process variables. For example, if harder material than usual needs to be processed, this condition can be detected by the integral process control charts and correspondingly the speed of the machine can be reduced to get the acceptable process output signals. Of course, in order to achieve such counter actions by the forgiving process parameters (correction of process speed to compensate for the hardness of the material), both process knowledge and process flexibility must exist. For many manufactured products such process knowledge either already exists or can be developed with the use of statistical methods. The issue of process flexibility is not very difficult.

Predicting the unknown has never been easy, but statistical thinking (SPC) and high speed computers (automation) at least make the task approachable for most of the unknown problems, and solvable for some problems which cannot be approached by any other equally effective means.

CONCLUSION

Companies in the the automotive industry are spending lots of money trying to improve the productivity with which cars are placed on the market. Among many productivity ideas being implemented throughout this industry, the Statistical Process Control and Automation are consuming a significant proportion of the budget.

This paper has analyzed the close relation between Automation and SPC. SPC provides the guidance as to what needs to be done whereas automation makes sure that it gets done!

This paper also described the distinction between Functional Automation and Process Control Automation. In functional automation the speed or efficiency of the process in generating output is a primary focus and the output consistency is of little or no consequence. In Process Control Automation, the consistency of the output is a primary focus, whereas the increased speed of the process output is a secondary benefit.

Process Control automation is further broken down into Deterministic Controls and Probabilistic Controls. Deterministic Controls are those that control the well-established relationships between causes and process output. If these relationships are disturbed, the statistical signals can be picked up and either an automatic feedback loop can be provided to make a necessary process correction or the process can shut down to permit a manual process correction. Use of SPC in such cases, can only establish the priority with which the funds should be invested in automating deterministic controls. Probabilistic Controls, on the other hand, are those that first requires us to make an attempt to understand the relationships between the process output and the disturbing causes through the use of control charts. Several steps are required in executing SPC on a given process, starting from measuring process output to determining and correcting the disturbing causes. These steps can be automated by installing probabilistic controls. Several stages of Probabilistic Control Automation were discussed. There is no effective way, other than SPC, to achieve this.

COMMENTARY

Though automotive related industries are applying good ideas in form of SPC and AUTOMATION to improve productivity, they are not necessarily doing it in correct strategic order. As a result, there is a need to question and further understand the relationship between SPC and AUTOMATION.

First of all, there is plenty of evidence to indicate that the robotization of a manufacturing processes is usually implemented with the primary focus on the speed rather than the consistency of process output. One cannot and should not argue against the benefits of speedy operation, if a proportionate amount is also invested in PROCESS CONTROL AUTOMATION. Such is not the case, however. There is sufficient evidence to suggest that a disproportionate amount of funds are being spent on Functional Automation as compared with the spending on Process Control Automation.

Secondly, there is also evidence that the funds going toward Process Control Automation are disproportionately distributed in favor of Deterministic Process Controls. Actually, there is an acute need to invest in understanding the relationships between the patterns in the process output and the corresponding contributing causes rather than to invest in deterministic controls. This can be achieved by the use of probabilistic controls. If the process of applying probabilistic controls is speeded up through the use of automation, there are more benefits to be derived than to simply install deterministic controls without knowing the priorities. The priorities for installing deterministic controls can only be established through the use of probabilistic methods.

Therefore, any company considering automation must first understand the balance that must exist between investing in Functional Automation, Automated Deterministic Process Controls and Automated Probabilistic Process Controls. If it is unclear as to how funds should be distributed among these three forms of automation, SPC should serve as a conclusive guide toward establishing priorities.

Automotive related industries know that their survival is at stake. They know that the funds need to be invested. But they need to be invested strategically in upgrading the machinery that produces products. They also know that this machinery must be automated to compensate for the high cost of labor and the inconsistency of output compared with overseas competition. What they don't quite understand is the delicate investment balance that must exist in implementing various phases of automation. To understand the power that lies in talking about SPC and automation together, they should focus ON DOING THINGS RIGHT RATHER THAN DOING THINGS FAST.