REVISITING PRE-CONTROL CHARTS: A CASE STUDY OF THE AUTOMOBILE COMPONENT MANUFACTURER

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Research report in partial fulfillment of the requirements for the degree of
Masters of Business Administration

2006

DEDICATION

This piece of work is dedicated to my father Mr. K.V.L.N. Murty and my mother K. Nagalakshmi for their continues support and love, to my brother K.R. Suresh Kumar whom I see as a source of inspiration and to my grandmother A. Kalavathi for her love and affection. Special appreciation to my fiancé Sonika Pandita for being very understanding and patient and to my house mates B.Vasudevan and Solaimurugan for there support and encouragement.

ACKNOWLEDGEMENT

First and foremost, I would like to thank and appreciate my supervisors Assoc Prof Mr T. Ramayah and Dr. V. Arumugam, for their guidance and continues support in preparation of this thesis. This research would not have been materialized without their guidance. My appreciation also goes to the staff of Munjal Auto Components, for all the assistance rendered in carrying out this research. Next, my appreciation goes to all the lecturers and staff of USM's Management school, who had guided me and provided me support, directly or indirectly. My special thanks go to Assoc. Prof. Dr. Yusserrie Zainuddin. Lastly I would also thank all my MBA course mates, for providing plenty of fun in class, learning through each others professional experiences and making study much enjoyable.

Thank you

TABLE OF CONTENTS

LIST OF TABLES Page

LIST OF FIGURES Page

ABSTRACT

This experimental study looks into the benefits of the Pre-Control chart for an automotive component manufacturing company. This paper can be divided into two parts; first part investigates whether the Pre-Control chart could be used as both process control chart and a defect control chart, and in the second the various factors that can cause variation in the output variable bore diameter. The most significant factors affecting the final output variable were identified using discriminant analysis. The sample collected for the analysis of the Pre-control chart is 840 components per eight hour shift, observations recorded on the Pre-control chart are two components for every 40 components, and sample is collected over 3 months time. A sample of 100 continues data points were collected for the analysis of the factors influencing the output variable. Study concludes that Pre-Control chart is a sound defect control chart; it is not a good predictor of the process capability. So it is recommended for use in automotive firms with an additional chart to monitor the process capability like the X bar R charts or X bar S charts. The major factors affecting desired output were identified as temperature of the work piece during the boring operation; operator's influence was found significant as operator is responsible for setting the parameter to bring the process back to the mean of the control limits, and flow rate of the metal during the forging process was also found to be significant. The other factors like the tool type, material of steel, speed of rotation of the chuck were not found to be significant to determine the variability in the process.

ABSTRAK

Kajian eksperimental ini menyelidik kebaikan carta pra kawalan untuk kilang pembuatan komponen automobil. Kajian ini dibahagikan kepada dua bahagian; bahagian pertama adalah untuk mengkaji samada carta pra kawalan boleh digunakan sebagai carta kawalan proses dan carta kawalan kerosakan. Bahagian kedua, faktor-faktor yang menyebabkan variasi output pada diameter pengerudian. Analisa diskriminan digunakan untuk mengenalpasti faktor-faktor yang mempengaruhi output. Sebanyak 840 komponen untuk setiap shift selama 8 jam dikumpul untuk analisa carta pra kawalan. Pemerhatian dilakukan setiap 40 komponen; 2 sampel dinilai dan dicatat. Sampel ini dikumpul dalam jangkamasa tiga bulan. Sebanyak 100 data dikumpul untuk menganalisa faktor yang menpengaruhi output. Dapatan kajian menunjukkan bahawa carta pra kawalan adalah carta kawalan yang signifikan tetapi ia bukan tolok jangka untuk kebolehan process. Oleh itu, adalah dicadangkan untuk kegunaan industri automotif bersama carta X bar carta R atau carta X bar carta S. Faktor utama yang dikenalpasti mempengaruhi output adalah suhu bahan yang digerudi, pengaruh operator juga didapati mempengaruhi output secara signifikan kerana dia bertanggungjawab untuk memasukkan parameter supaya process kembali kedalam julat kawalan dan suhu besi tersebut semasa process *forging*. Faktor-faktor yang lain seperti jenis peralatan, pembekal besi dan kelajuan didapati tidak menyumbang secara signifikan.

CHAPTER 1

INTRODUCTION

1.1 Situation Background

Efforts to reduce both the variability of a process and the production of nonconforming items should be ongoing because quality improvement is a never ending process. Whereas process control deals with identification and elimination of special causes (those for which an identifiable reason can be determined) that force system to go out of control (for example, tool wear, operator fatigue, poor raw materials), quality improvements relates to the detection and elimination of common cause. Common causes are inherent to the system and they are always present. Their impact on the output may be uniform relative to that of special cause. To continuously bring down the defective rate management is deciding on whether or not to use a chart like Pre-Control chart to monitor the process variability and as a defect control chart. Before the ISO/TS16949/2002 audit, firm was mainly using individuals charts like run charts and X Bar R charts to know if the process was in control as per the requirement.

The problem the current industry Munjal Auto Components (MAC) was facing is, with the rejection level of the Gear M2. M2 is a notation given to one of the four gears that hook up on to the main shaft, and the whole assembly is then fitted into the gear box of a motor bike. The firm is a direct on-line supplier (DOL) to Hero-Honda motors Ltd (HHML) which is the largest manufacturer of motorbikes in the world. Gear M2 is supplied to Hero-Honda as a semi finished or finished component. Semi finished component is processed only up to the machining and finish component will go through the heat treatment process and then dispatched to the customer who is

HHML. The impact is massive when a reject component leaves the premise of the company which would directly reach the assembly line for it to get seated inside the gear box, at Hero-Honda the assembly time for one motorbike is 17 seconds so a wrong component entering into the line will cause the line to stop, as it can be seen from the Appendix 1. the rejection rate of the gear from March to September for semi finished components is averaging around 1500 parts per million. The highest alert was sounded to reduce the rejection rate, as the firms warranty would be under scrutiny and may loose the contract to supply HHML. Management could not come up with a convincing answer to the issue with their experience and knowledge.

During this time the firm was preparing for the ISO/TS certification as the HHML wants all its suppliers to be TS certified. During the technical specification (TS) audit, the auditor urgently advised to 'improve' the power of the SPC system by introducing Pre-control chart. A set of runs rules was selected to oblige the auditor, and as a result the chart was deployed. These Pre-Control charts gave many additional signals. However, it remained unclear whether these extra signals were caused by either an increased probability of a 'false' signal, or by out-of-control situations that were not detected before (such as changes in the spread). Moreover, the question was raised whether it was useful to add a Pre-control-chart to the existing system for faster detection of nonconforming units.

There are two prominent disadvantages in using X bar R charts they are Firstly we can get to a conclusion that the process is going out of control only after plotting for a minimum of 5 subgroups points by then it may become too late to trace back the batch of items that has been produced, it either enters the next process or it can leave for additional processing by a vendor or dispatched to customer, especially when the firm is a direct on line supplier (Just-In-Time) to its customer. The second and major

disadvantage with the X bar R charts is that the operator plots the graph, as the firms believes in giving total responsibility to the operator and holds him responsible for producing defective component. But now the question of over adjustment arises as it is in the discretion of the operator to modify the process mean depending on the situation so if the operator has a gut feeling that the process is drifting he may do adjustment that will alter the process mean and similar over adjustments often will change the original setting and can make the process go haywire and produce defective components. So the objective is to reduce such gut feeling to change the process and from the experiment it can be concluded that Pre-control chart with set of run rules can control the over adjustment made by the operators by giving them a clue of how much feed should be given to compensate for the wear allowance on the tool.

This paper can be divided into two parts. In the first part we investigate whether the Pre-Control chart would be useful in the particular runs-rules context of the firm under investigation. And in the second the various factors that can cause variation in the out-put dependant variable.

With the release of ISO/TS 16949:2002, there came sweeping changes to the way Firm need to implement, maintains, and continually improves their quality management systems. The new emphasis was now on organization identification and managing a defined series of unique business process and sub-processes effectively and efficiently so that total customer satisfaction is assured. The 2002 version of the technical standard is business-focused and offers an organization more flexibility in implementation. The goal of this technical specification is the development of a quality management system that provides for continual improvement, emphasizing defect prevention and the reduction of variation and waste in the supply chain. This technical specification, coupled with applicable customer-specific requirements,

defines the fundamental quality management systems requirements. Only when customer-specific requirements are coupled with ISO/TS 16949:2002 do quality management systems become complete and meaningful in meeting the requirements of a particular subscriber within the automotive industry. So there was a need to address this problem and show considerable improvements for the firm to get certified by the auditing body. Customer specific requirements are those that are agreed to between the supplier and the customer. They typically fall into the following category.

a) Part specific requirements (dimension, materials, performance characteristics.
b) Delivery requirements
c) General requirements (PPAP, APQP, etc)
d) Process requirements (Forging, Annealing, Hobbing, etc.)

1.2 Company Background

Munjal Auto Components (MAC) (a division of Munjal Auto Industries Limited) established in 1998. is a TS16949 certified firm and part of the Hero Group. Headed by Mr Neeraj Munjal who is the director with good leadership skills and a strong vision, has seen tremendous growth with its 8 year presence as a Hero group company**,** MAC is a largest Manufacturer of Transmission Gears & Shaft and a Major Supplier to M/s Hero Honda Motors Ltd which is the world's largest motor bike manufacturing firm**.** Hero Group ranks amongst the Top 10 Indian business houses comprising 18 companies. This renowned corporate giant's turnover during the fiscal year 2003-2004 was US $1.8 billion.

Munjal Auto Components has the Sate-of-art Japanese technology, with monthly turn over of RM 1500,000 and also supplies shafts and pistons to Rane Steering and

M/S Robert Bosch .This Company is situated on the outskirts of booming modern industrial town of Gurgaon in village Binola. The firm has in all 310 employees both executive staff and non executive staff put together.

1.3 Problem Statement

To bring down the rejection level of the gear to less than 500 parts per million defective and can the management depend on the Pre-control charts to give indication of the process health and defect identification

1.4 Research Objective

. Operators change the parameters like speed feed etc on the machines due to production pressures, high speed and feed rates can give rise to elevated temperatures triggering a chain effect giving raise to other factors which may have a combined effect on the quality of the output work piece.

1. In this study the primary reason for placing priority on the factors that influence the output quality, is to cut off the synergistic effect of the combination of various factors. The synergistic effect is the action which creates a multiplied effect larger than the combined effect of the several factors involved. Even if the individual factors has quite small possibility it will induce other factors that create a greater effect, when combined with other factors trigger a chain reaction. Since there is a possibility, it is important to make every effort to repair slight variations one-by-one to prevent them from developing into serious conditions.
2. The second reason for placing priority on the slight defect elimination is that there is the necessity to summarize the possible causes which have influence

over the dependent variable (output quality) the bore diameter and to bring to light the main factors influencing the output

3. The main objective is to provide the operator with a chart which is both robust to detect nonconforming products and on which operator can depend on to monitor the process health. So the use of Pre-Control chart is under scrutiny

1.5 Research Questions

1) What effect does temperature during the boring operation have on the out put quality of the bore diameter?
2) What effect does the flow of the metal during the forging process have on the output quality of the bore diameter?
3) What role the operator plays in determining the out put quality of the bore diameter?
4) How will the supplier of the steel in terms of material have an effect on the out quality of the bore diameter?
5) How will different cutting tools from different suppliers effect the output quality of the bore diameter?
6) What influence will speed have on the output quality of the bore diameter?

1.6 Significance of the study

This paper will benefit automobile component manufacturers to implement a pre-control chart which is easier for an operator to plot and reduce the over adjustments made by operator to correct the process. The chart will also give a rough idea of how much to adjust to get the process back to the mean of the control limits.

The Pre-control chart can be used for operations like Turning, Grinding, Boring, Shaving, Shaping, Milling etc.

The benefits to the current industry are:

1. Provide identification for capital budgeting (for the cost required if plant wide implementation is to be perused)
2. Provide assurance to management, on the suitability of the use of Pre-control chart for their company. For a better process control
3. Testing in small way before launching to cover entire firm can help save time and effort and the failure or success could be judged and decision could be made by the management.
4. Operators will no more be dependent on their gut feeling to know if the process is going out of control, they can take a quick action by reducing the nonconforming units.

1.7 Variables Definition

Factors

A factor is one of the controlled or uncontrolled variables whose influence upon request is being studied in the experiment. A factor may be quantitative, temperature in degrees. A factor may also be qualitative, different operator, tool type.

Process

A collection of activities that takes one or more kinds of input and creates output that is of value to the customer either internal or external.

Boring

Enlarging a hole made by a previous process. A single-point tool is fed linearly and parallel to the axis of rotation on to the work piece.

Temperature

In the study temperature refers to the conduction of heat by the metal during the metal turning process , turning is an metal cutting operation where in the cutting tool is kept constant with respect to the turning work piece which is held in place by a chuck to get the desired shape. The temperature of the work piece while in operation is measured by pyrometer. Higher temperatures will be encountered at the larger diameters on the work piece.

Tool type

The firm purchases 3 varieties of inserts from 3 different suppliers that are used as a cutting medium, while cutting process is taking place there is a lot of generation of heat.

Material supplier

There are two suppliers offering the firm the alloy steel SCM415Hv a steel used exclusively for making gears.

Flow

The study of plasticity is concerned with the relationship between metal flow and applied stress. Since the input to the machine shop is from Forging high chance of uneven flow of metal is possible. If a series of roughing cuts causes the work piece to become unbalanced, the problem will be compounded when the speed is increased to take finishing cuts. As a result, the reasons for problems in achieving the required accuracy and surface finish may not be apparent until the machining operation has progressed to the finishing stage.

Speed

Cutting speed: refers to the relative surface speed between tool and work, the work, the tool, or both, can move during cutting. Because the machine tool is built, to

operate in revolutions per minute, some means must then be available for converting surface speeds into revolutions per minute (RPM) measured in Meters/Minute, the study is conducted on a Mazzak T6 CNC Turning Machine and speed represents the number of meters the machine can cut in one minute.

1.8 Organization of the thesis

This study is divided into 5 chapters. Chapter1 consists of, situation background company background, problem statement, research objective, research questions, significance of the study, definitions of the key variables and organization of the dissertation. In chapter 2, focuses on the previous research done in the areas and conclusions made by the researchers. Chapter 3 discusses the methodology, theoretical framework and hypotheses, introduction research design, study elements, sample selection, time line of the study, data collection methods PFMEA, Pareto Charts, Measurement System Analysis, process validation/revalidation, addressing the change management issues, Construction of the Pre-control chart results, discriminant analysis and Summary. Chapter 4 discusses the results and chapter 5 consists of discussion and conclusion of the study.

CHAPTER 2

LITRATURE REVIEW

2.1 Review of literature

The impact of statistics in industry and the role of statisticians by Ronald and Does (2001) mentioned, thinking in industry means that all work is regarded as a series of interconnected process, that all process show variation, and that reduction in variation is the key for continues improvement. They also said SPC has become an important part of quality control activities and is definitely accepted as one of the main tools of quality management industry

Statistical Quality control (SQC) principles have grown from the work of Shewhart, Deming, Juran and Taguchi which have later grown into Statistical process control (SPC) these analytical tools were developed to monitor product, and production process variability. Lean manufacturers use SPC/SQC to monitor and adjust their processes and output to increase their quality. Collected data is generally illustrated in graphs, control charts and diagrams e.g. control charts, check sheets and flow charts. The aim is to predict and reduce variability in the production process and thus increase the quality of the production output. Statistical quality control replaced the individual inspection with random sampling inspection. SPC/SQC focuses on the quality of the workmanship and functional reliability and not on the product design quality therefore rather than "proactive measure" it is a "reactive quality control measure." Variation is a fact of life; it is every where and is unavoidable. Even a brand new machine cannot hold perfectly to the target setting. The purpose of a control chart is to detect any unwanted changes in the process. These changes will be signaled by abnormal points on the graph. Extensive research by Dr. Shewhart

indicated that by establishing upper and lower limits at three times the standard deviation of the process (plus and minus, respectively), 99.73% of the common cause variation would fall within these limits. A process is said, therefore, to be in .statistical control. When the process measurements vary randomly within the control limits; that is, the variation present in the process is consistent and predictable over time. The upper and lower control limits are not the same as tolerance or specification limits. Control limits are a function of the way the process actually performs over time. Specification, or tolerance, limits are a function of what your process may have been designed to do and may not necessarily have any direct relationship to the actual performance of the process.

In summer of 1999, quality managers in the German automotive industries organized a work shop with the title "SPC on the test bench" the trend in current quality management standards (like e.g. QS 9000) is to put more emphasis on the use of statistical methods, and in particular on implementation of SPC, the experience in industry was that use of current SPC tools was not adding value to the industry. The industry representatives reported on numerous cases where process perpetually signaled out-of-control situation although no cause could be assigned and, consequently no corrective action could be designated. A study of 1000 different processes in the industry had shown that about 90% of the process exhibited variation of the charted averages that was significantly larger than what could be tolerated according to the calculated within subgroup variance.

The experience from the practical implementation of SPC in the industry was that 'theory' is far from practice. In their paper authors Iwersen, Mclgaard and Thyregod, (2003) concluded by emphasizing the importance of distinguishing between charting aimed at identification situations where minor process adjustments are needed to

compensate for process disturbances, and charting aimed at demonstrating a state of 'statistical control' with a predictable long term distribution of process output. For the later purpose they discussed the modeling of process variation by means of a hierarchical model for normally distributed measurements.

Having determined the quality problems in mass production in a medium-size firm chosen as a pilot study all the process from casting to machining were investigated. The problem of low quality arising during production was eliminated by the statistical quality control of a given product in their paper Elimination of the Quality Problems Encountered in Mass Production by Using Statistical Quality Control by authors Motorcu and Gullu, (2002) in their experiment used X bar R charts with support of statistical calculations for the problem of low quality concerning the part and undersized size causing high costs. The underlying reasons for parts not meeting the desired quality were identified and the correct parameters presented in their work.

Performance of cutting tools is highly dependent on the cutting conditions i.e., cutting speed, feed, feed-rate, and depth of cut as found from the research work of Toenshoff, Arendt and Amor (2000)

Cutting speed and depth of cut significantly influence tool life as researched by Erol (2001) Increased cutting speed and depth of cut result in increased temperatures at the cutting zone. At elevated temperatures chemical wear becomes a leading wear mechanism and often accelerates weakening of cutting edge,

Pre-Control was developed by Shainin in 1952 and is currently used by hundreds of companies to bring fraction defective production to nearly zero parts per million. Pre-Control chart is a simple sensitive method for achieving this goal. Pre-control, also called stoplight control, is a quality monitoring scheme similar to a control chart. However, the goal of Pre-control is the prevention of nonconforming units rather than

the detection of a lack of stability. The appeal of Pre-control is due mainly to its ease of implementation, lack of required assumptions, and reported successes. However, it has come under much criticism, as many of its decision rules appear ad hoc. In his article Steiner, (1998) compares the various PC schemes and contrasts them with more traditional control charts such as acceptance control charts and X bar charts. He also mentioned modified PC uses control limits, as defined in Shewhart charts, rather than tolerance limits to define the boundaries between green, yellow and red units. Modified PC is very similar to Shewhart type charts such as X bar charts and has the same goal namely statistical control of process. The first obvious difference according to author is that PC uses only information from the grouped observations, whereas traditional control charts like X bar uses variable data. Conclusion drawn by the author is that classical and two-stage PC are good methods when the process standard deviation lies in the range $T/15 \leq \sigma \leq 11T/75$, where T is the tolerance range. Two stages PC are preferred over Classical PC unless the additional sampling required is very onerous. Modified PC, on the other hand, has the same goal as an X bar chart, but is shown to have an excessively large false alarm rate, and is thus not recommended.

The various Pre-control schemes contrasts with more traditional control charts such as acceptance control charts and X-bar charts. A procedure with statistical validity, called Pre-Control is very useful in Job Shops; especially where machine shop operations are the manufacturing methods. Cook and Hardy (1989) found classical statistical control methods are satisfactory for long runs of consistent materials, many current products are customized through computer-assisted design and manufacturing, which affect the number of runs and the homogeneity of input and output materials.

There is a need to be "on target" and "in control" as soon as possible to minimize losses from the production of non-standard material. "Pre-Control", which was created in 1952, is successful in achieving this goal for discrete items and batch processes. Vallance and Wallace (1993) points out that a company cannot reach the “Holy Grail of zero defect” if a “product is poorly designed from the start.” They also proposed that workers “participation, responsibility and ownership” will result in an increased productivity and also quality products and services.

Pre- control is a technique that helps shop operators to control the process so that defective parts are not produced. Although simple to understand for even the shop operators, PC is statistically robust. Unlike SPC where we need 25 subgroups before we can draw control limits and conclusions, Urdhawareshe(2002) also states PC starts giving feedback about the process from the very beginning making it highly responsive to the process signals, that too without charting. The author concludes by saying although PC is very simple to use, it is not a substitute for control charts. The purpose of control charts is to monitor process to detect presence of assignable causes, if any. Process log is maintained with control charts making it a useful tool to understand variation with time and relate it to various events. PC on the other hand is a simple tool that helps to prevent manufacture of defective parts. It does not require any charting by the worker.

In his article Controversies and Contradictions in Statistical process control Woodall (2000) mentions “statistical methods play a vital role in the quality improvement process in manufacturing and service industries” Author discusses the relationship between hypothesis testing and control charting, the role of theory and the modeling of control chart performance, the relative merits of competing methods, the relevance of research on SPC and even the relevance of SPC itself. The article