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PC BASED GAUGING SYSTEM USING ARM MICROCONTROLLER

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Abstract: ***This system provides dimensional measurement of machined automobile components. The system is based on the field of Metrology which has numerous industrial applications dealing with machined parts. Another exclusive feature provided by this system is the SPC analysis. This includes live plotting of various statistical graphs such as Run chart, Individual chart, Moving Range chart and histograms, for each dimension. Basic parameters such as standard deviation (σ), process capability (Cp) and process capability index (Cpk) assume a great importance when categorization of any process as capable or stable is considered.***

Keywords—*Gauging, LVDT, LPC1778, AD698, SPC Analysis*.

I INTRODUCTION

Dimensional measurement is the measurement of geometric features of an artifact. This may involve measuring the size, distance, angle, form or co-ordinate of a feature on an artifact, and the artifact itself may be anything at all - the height of a person, the diameter of a beer barrel, the length of a truck, the radius of a ball and soon.

In manufacturing, dimensional measurements are vital in monitoring and controlling the variations inherent within any manufacturing process. Simple things like tool wear can be picked up as a drift in size of a turned component within the allowable tolerance band, corrective action can be taken in good time.

More complex interactions may require a more detailed measurement process – such as periodic assessment of a whole car body from an assembly line. It is possibly not necessary to measure every car body, but if you measure every feature on every fiftieth body then you have some statistical control of the process.

II LITERATURE REVIEW:

Some of the systems which are being widely used in industries are summarized as follows:

1) MARPOSS [5]

MARPOSS provides gauge makers the components they need to build gauging stations and fixtures. The system is shown in the following figure.

Figure 1 MARPOSS Gauging System [5]

Components provided by this system are:

- Probes and measurement transmission elements: mechanical components and sensors

- Indicators and display units: mechanical and electronic units to elaborate and display results
- Signal converters: to convert sensor values to digital signal.
- Data acquisition systems: interface units to connect analog and digital sensors to an industrial PC
- Industrial Computers (embedded computers, panel PC and workstations) for data processing and control
- Application software to create distributed shop-floor data acquisition systems for Statistical Process and Quality control (SPC).

2) MECC: Compact measuring computer [2]

The compact measuring computer MECC is a robust and universal industrial computer for manual and automatic collection of measured values with statistical analysis. Programmable measuring sequences and control functions allow the automatic operation of multi-gauging fixtures to the transfer of correction values to CNC machines. By the usage of IMBus modules the measuring computer can be individually configured for any application with 1...64 measuring inputs.

- Compact and robust construction with solid, sealed metal case (optional cover cap for IP64), passive cooling and 8” TFT-Display (800 x 600) with touch screen, adjustable angle of tilt - IMBus modules for inductive probes, incremental systems, pneumatic gauge heads, sensors with analogue voltage or current outputs and gauges with data output - Profibus- and PLC compatible in / outputs for control applications - Standard PC-connections USB, LAN and RS232 (COM-Port).

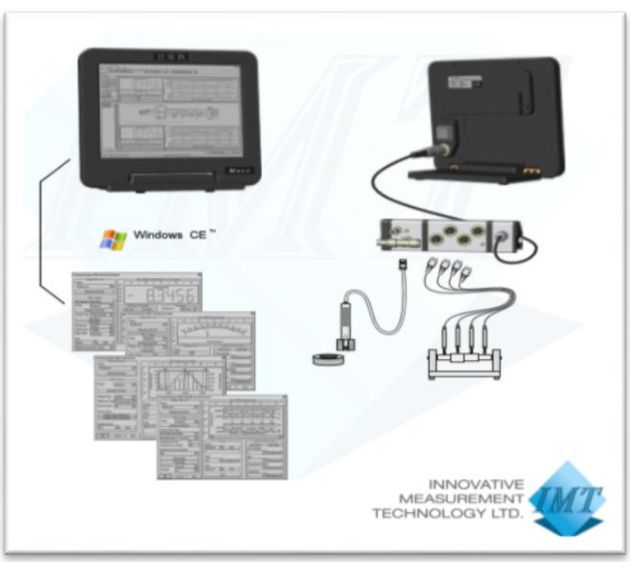


Figure 2 MECC Compact Measurement [2]

GAUGING:

A gauge in science and engineering is a device used to make measurement in order to display certain dimensional information. A wide variety of tools exist which serve such functions, ranging from simple pieces of material against which sizes can be measured to complex pieces of machinery.

TYPES OF GAUGES:

1. Plug Gauge:

A Gauge in the form of plug, used for measuring the diameter of a hole.

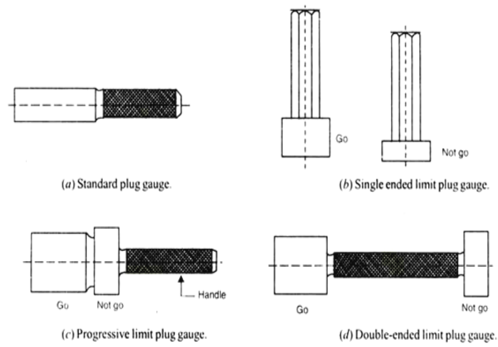


Fig. 1.41. Types of plug gauges.

2. Pin Gauge:

The Pin Gauge is the pin shape according to fixed size precisely

The primary purpose of Pin Gauge is to measure and inspect the diameter of holes large than 75mm, such as automobile cylinder, it also can be used as a test bar for geometric deviations measurements.

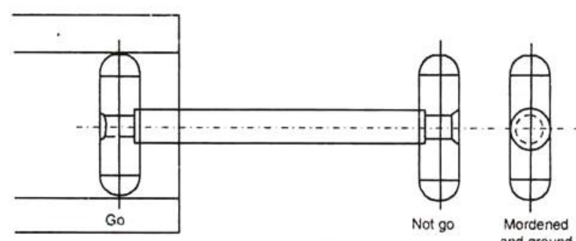


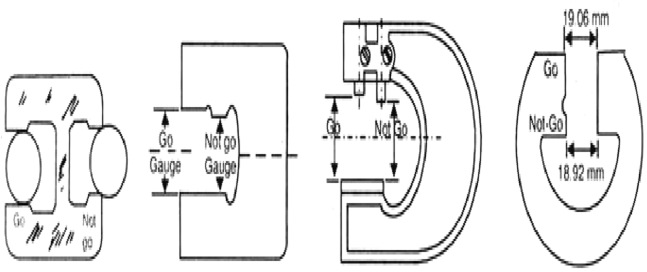
Fig. 1.42. A Pin Gauge.

3. Ring Gauge:

A Ring Gauge is a cylindrical ring of a thermal stable material, often steel, whose inside diameter is finished to gauge tolerance and is used for checking the external diameter of a cylindrical object.

4. Snap Gauge:

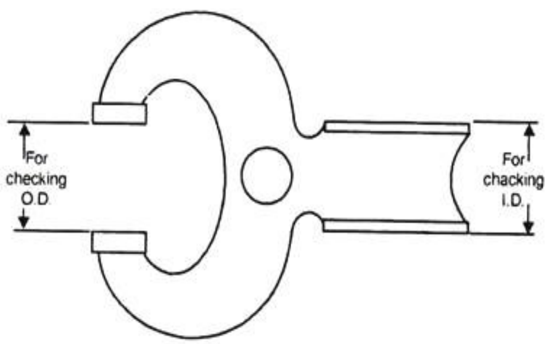
A Snap Gauge is a form of go or no go gauge. It is a limit gauge with permanently or temporarily fixed measurement aperture which is used to quickly verify whether an outside dimension of part matches a present dimension or falls within predefined tolerances.



(a) Double-ended. (b) Combined. (c) Adjustable gap. (d) Fixed.

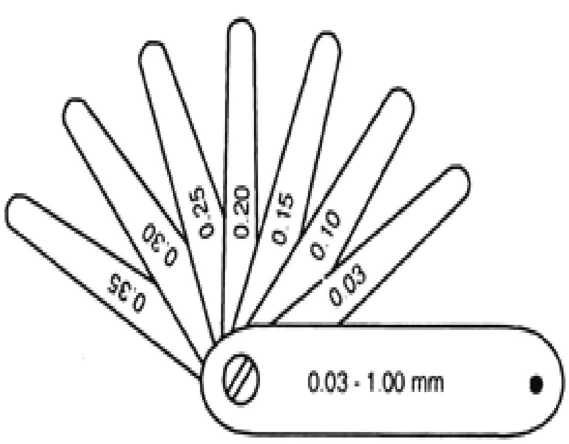
5. Caliper Gauge:

Usually caliper is an instrument used for measuring thickness and internal or external diameters inaccessible to a scale, consisting usually of a pair of adjustable pivoted legs.



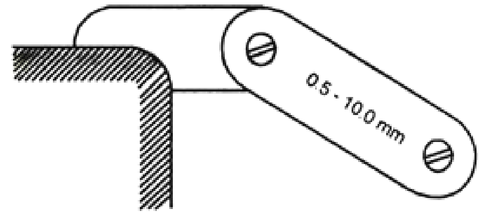
6. Thickness or Feeler Gauge:

The definition of Feeler Gauge is a thin metal strip of known thickness used to measure a narrow gap or to set a gap between two parts.



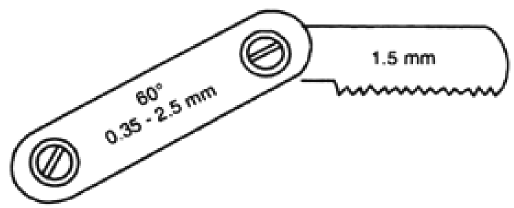
7. Radius or Fillet Gauge:

A Radius Gauge also known as Fillet Gauge is a tool used to measure the radius of an object.



8. Screw Pitch Gauge:

A Thread Gauge also known as Screw Gauge or Pitch Gauge is used to measure the pitch or lead of a screwed thread. Thread Pitch Gauges are used as a reference tool in determining the pitch of a thread that is on a screw or in a tapped hole.



III BLOCK DIAGRAM OF SYSTEM:

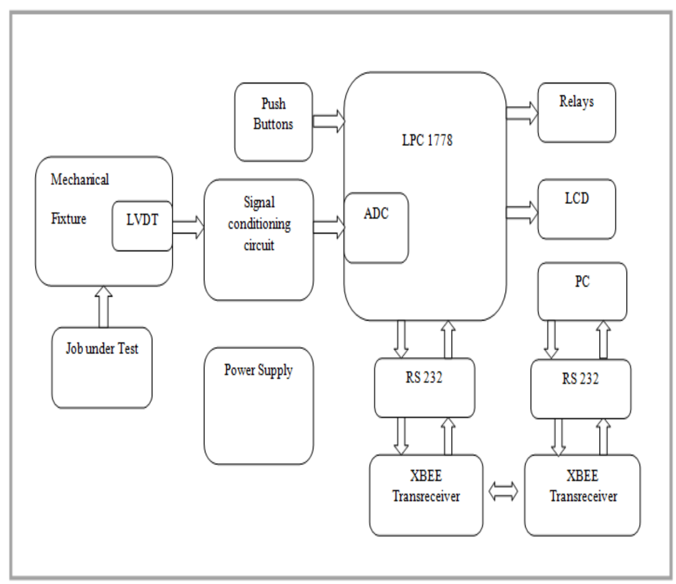
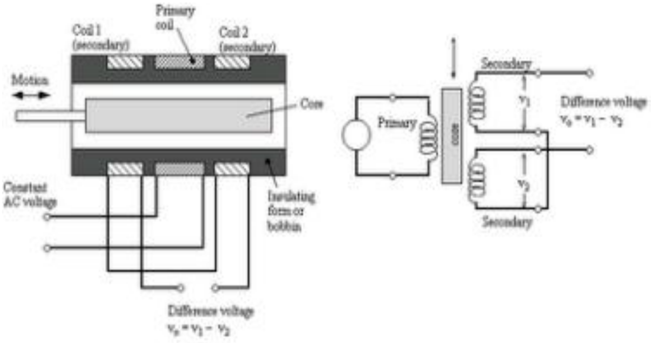


Figure 3:-Block Diagram of PC based Gauging System

Power Supply: Provides DC power to all circuits at different voltage levels (3.3V,+5V,-5V) as required by each individual modules.

Mechanical Fixture: Used to clamp or hold the measuring component.

LVDT: Used to measure dimensional variation of job under test.



Signal conditioning circuit: Provides AC excitation signal to LVDT. AC Output from LVDT (in millivolts) is amplified to the required level for ADC.

ARM Controller: LPC 1778 is used to control all the required functions.

Relay: Indicates 'HIGH', 'OKAY', 'LOW' status of the job under test.

Wireless communication System: Sends data to remote PC.

PC: Received data is processed and its SPC analysis is calculated and displayed.

IV SYSTEM REQUIREMENTS:

Generalized list of hardware components and software used is given here:

HARDWARE

1. Mechanical Fixture
2. 2 LVDT Probes
3. Power Supply
4. Microcontroller PCB
5. Peripheral PCB
6. 20x4, 3.3V LCD Display
7. RS232 wireless module
8. PC
9. Push Buttons
10. Relays
11. Mounting Panels
12. Jobs Under Test

SOFTWARE

1. Keil µVision 4
2. Flash Magic
3. Visual Studio 2017

V GENERAL ALGORITHM:

This algorithm emphasizes on steps for operating this system. These steps are as follows:

1. Put master job in the mechanical fixture.
2. Press the Master switch to calibrate master in the system.
3. Place job under test in the mechanical fixture.
4. Two diameters at different lengths are displayed on PC.
5. Press TXD switch to register readings of both probes in PC.
6. On pressing TXD switch, Run chart, control charts, histogram, and SPC values are updated.
7. Follow the same procedure from step 3 for the next jobs to be tested.

Software Implementation:

Programming for this project has been carried out in 2 languages, which are Embedded C and VB.Net.

VI MICROPROCESSOR ALGORITHM

Programming for LPC 1778 has been done in Embedded C using the CMSIS standard. Its algorithm is as follows:

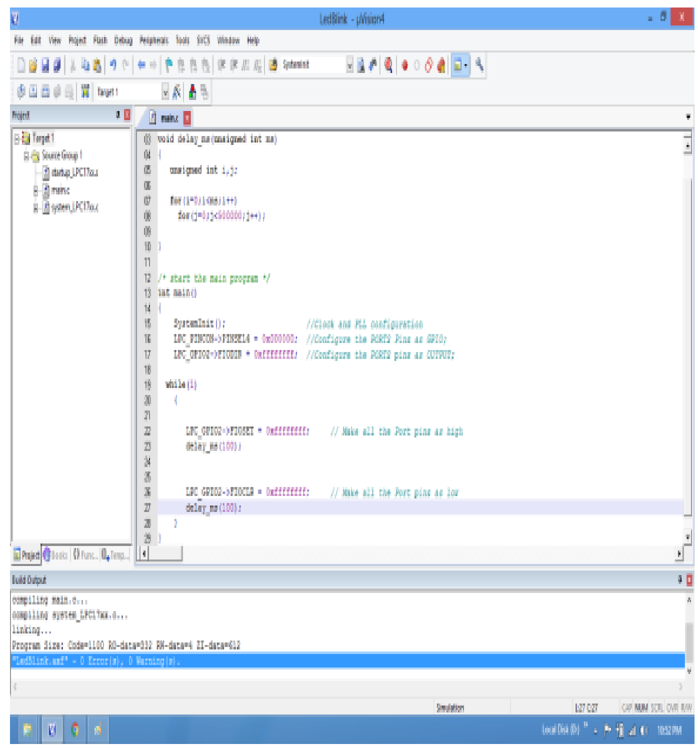


Figure 4: KEIL uv4 IDE

1. Initialize Clock and PLL Registers.
2. Initialize Timer, UART, ADC, and GPIO.
3. Initialize LCD.
4. Get readings from 2 probes on 2 channels of ADC.
5. Perform analog to digital conversation.
6. Transmit readings to PC.
7. Receive command byte from PC.
8. According to status of received byte, set or reset Relays and buzzer.
9. Send master and TXD switch status to PC.
10. Display ADC readings and communication counter on LCD

VB.NET BASED UI

VB.Net is used to design the user interface. Visual Studio 2017 is the IDE used.

VB.Net form controls used:

Windows Application Form:

It is the container for all the controls that make up the user interface. Every window you see in a running visual basic application is a form, thus the terms form and window describe the same entity.

Panel:

The Panel control is a container of other controls.

Buttons:

It is generally used to generate a Click event by providing a handler for the Click event.

Timer:

The Timer control allows you to set a time interval to execute an event after some interval continuously. It is useful when you want to execute certain applications after a certain interval.

Com port:

It is an object of the 'SerialPort' class, which allows two devices to communicate with each other. In this project, com port is used to establish a communication link between the PC and the microcontroller circuit.

Text boxes:

A TextBox is used to display, or accept as input, a single line of text.

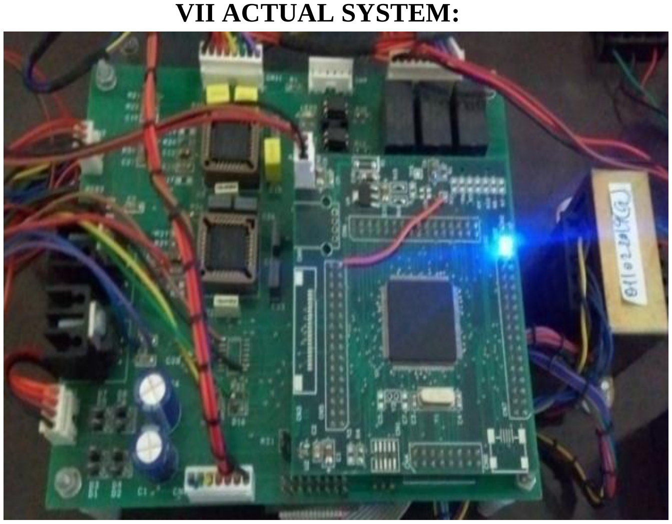
Labels:

It is used to display some informative text on the GUI which cannot be changed by the user during runtime.

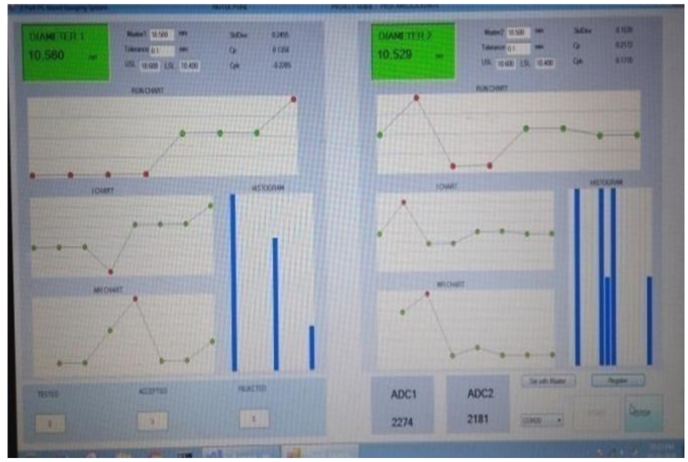
Picture Boxes:

The Windows Forms PictureBox control is used to display images in bitmap, GIF,icon, or JPEG formats. In this project, PictureBoxes have been used to plot all charts.

VII ACTUAL SYSTEM:



RESULT:VB SOFTWARE



The above figure shows Run Chart, I chart, MR chart and Histogram observed.

A run chart, also known as a run-sequence plot is a graph that displays observed data in a time sequence.

Individual (I) and Moving Range (MR) charts are used to track the process variability based on the samples taken from a process over the period of time

Histogram shows the deviation from mean value.

SPC ANALYSIS:

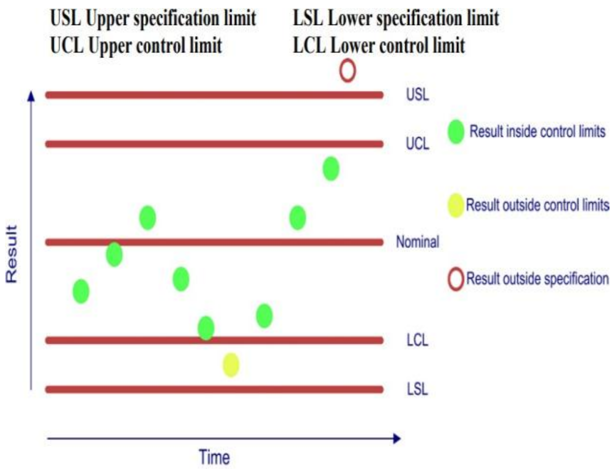
Statistical Process Control (SPC) is an industry-standard methodology for measuring and controlling quality during the manufacturing process. Quality data in the form of Product or Process measurements are obtained in real-time during manufacturing. This data is then plotted on a graph with pre-determined control limits. Control limits are determined by the capability of the process, whereas specification limits are determined by the client's needs.

Data that falls within the control limits indicates that everything is operating as expected. Any variation within the control limits is likely due to a common cause—the natural variation that is expected as part of the process. If data falls outside of the control limits, this indicates that assignable cause is likely the source of the product variation, and something within the process should be changed to fix the issue before defects occur.

TREND MONITORING DURING PRODUCTION:

Statistical process control (SPC) is the term used to cover the application of statistics to the control of industrial processes. In its simplest form this may involve measuring the size of every tenth item off the production line and measuring and recording the dimension on a graph that has the upper and lower tolerances marked on it.

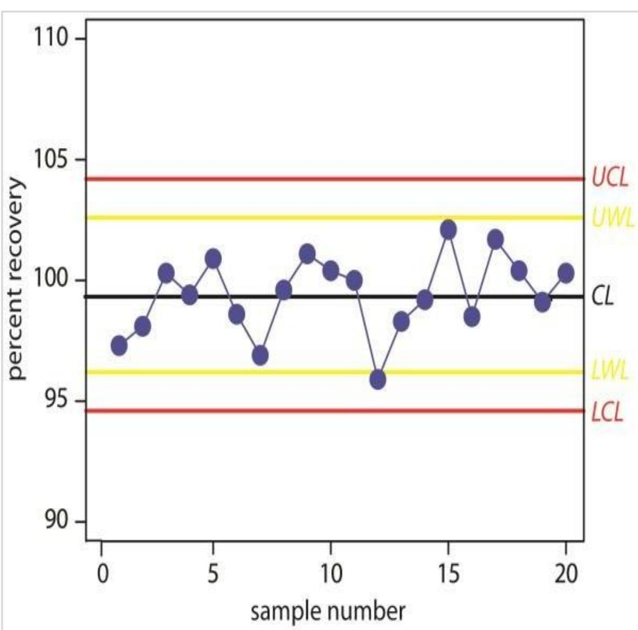
By taking note of the trends displayed on the graph it is then possible to predict when the process is going to produce components with dimensions that exceed the permitted tolerances, and take corrective actions, such as adjusting the tool setting. Figure shows a basic SPC control chart that plots the process variation with time. The basic aim of SPC is to minimize variation.

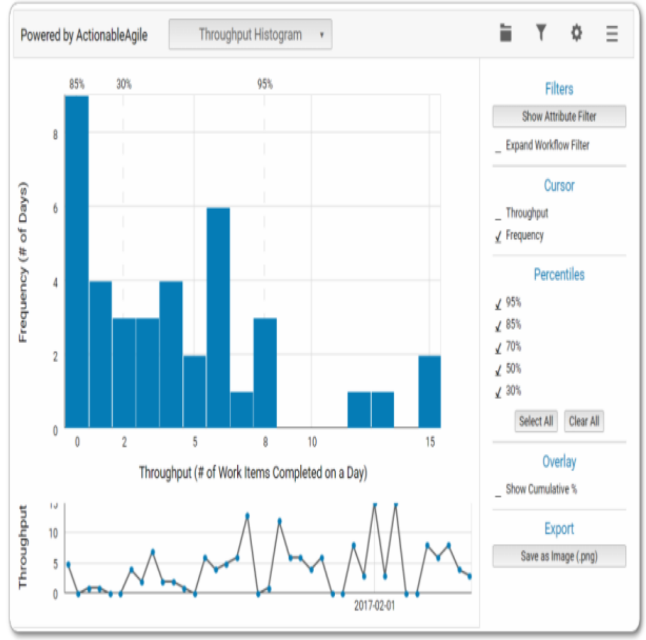


PROCESS CONTROL CHART:

The run chart and control chart are graphs used to study how a process changes over time. Data is plotted in time order. A control chart always has a central line for the average, an upper line for the upper control limit and a lower line for the lower control limit. These lines are determined from historical data.

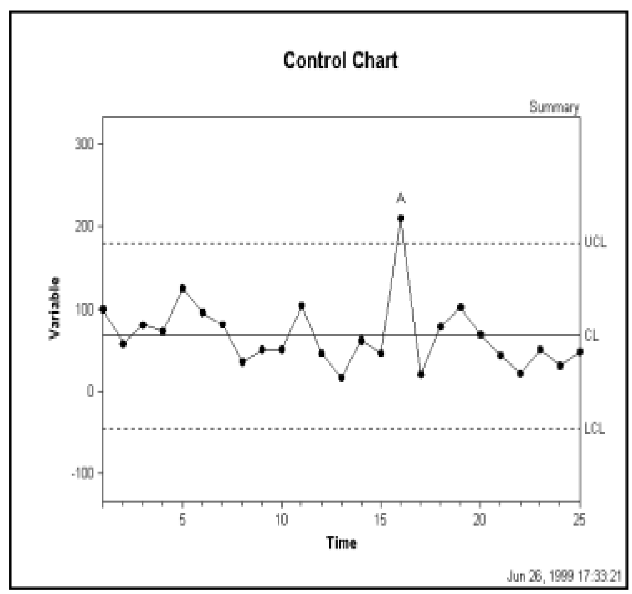
The run chart is a similar version of control chart but it displays only the upper specification limit, central line displaying average, and the lower specification limit.

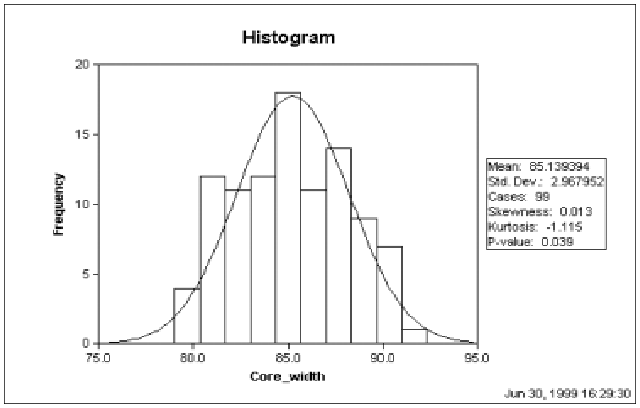




Control charts show the variation in a measurement during the time period that the process is observed. In contrast, bell-curve type charts, such as histograms or process capability charts show a summary or snapshot of the results.

Process control charts are fairly simple-looking connected-point charts. The points are plotted on an x/y axis with the x-axis usually representing time. The plotted points are usually averages of subgroups or ranges of variation between subgroups, and they can also be individual measurements. Some additional horizontal lines representing the average measurement and control limits are drawn across the chart. Notes about the data points and any limit violations can also be displayed on the chart.





PROCESS CAPABILITY CP:

Process Capability is a relatively simple statistical measure which provides an estimate on the level of process outputs which will be within permitted specification limits.

It provides a comparison between the output of a process versus the process specifications.

The process capability measure therefore allows comparison between desired levels of process capability and the actual performance levels of a process. Where a process is "acceptable as is", then controls methods such as Statistical Process Control can be applied to monitor the process, where the process is not capable and not meeting desired levels of performance, then action can be taken to investigate and have process improvements implemented to achieve the desired capability levels.

Cp is a measure of the potential of a process to provide output which is within upper and lower specification limits. The Cp measure does not take into account the centering of the process, so while Cp may indicate a potential to operate within the specifications, due to poor centering, the actual output may be skewed with resultant outputs outside of specification. Using Cp alone can therefore be misleading, but it does give a good indication of process potential.

As the Cp measure increases, the spread of the process output decreases, which is normally seen as positive. With variation decrease, the process output becomes increasingly homogeneous.

Cp will normally be used in conjunction with the Cpk measure, so that both centering and spread can be understood.

PROCESS CAPABILITY CPK:

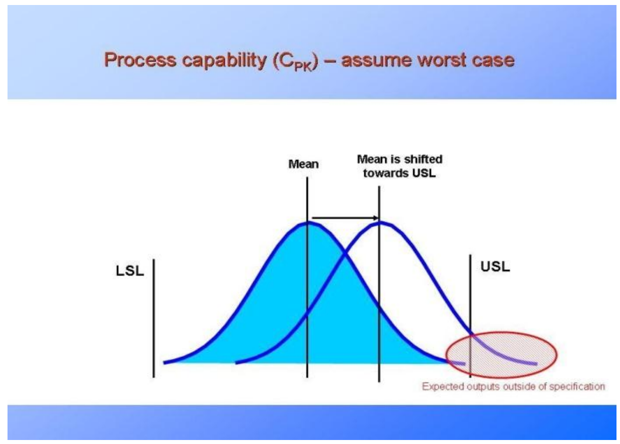
Cpk measures how much a process is in control by measuring its spread / dispersion within the specification limits.

In metric terms:

Cpk = {USL – Mean}/3σshort or {Mean – LSL}/3σshort

We take the worst case of either Cpk = {USL – Mean}/3σshort or {Mean – LSL}/3σshort

If the mean is centered, either approach gives the same result. If the mean is (say) closer to the Upper Specification Limit (USL), then we use USL – Mean, to get the worst case result, i.e. result which will generate the higher level of outputs outside of specification.



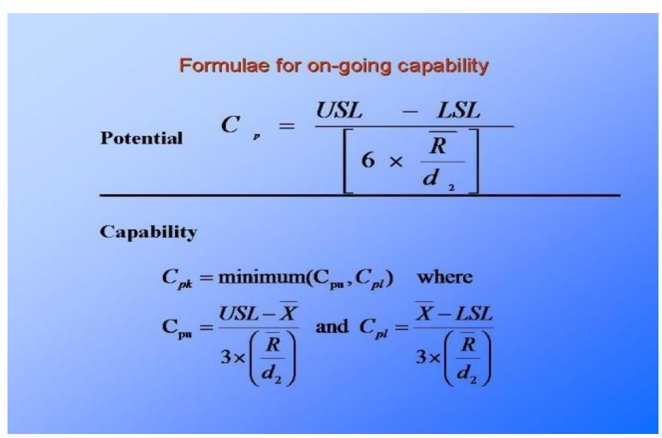
CAPABILITY VERSUS STABILITY:

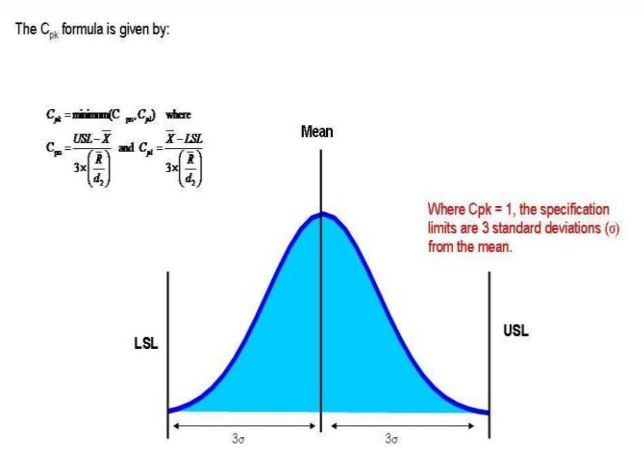
A process is Capable if the outputs produced are predictable to be within specification.

A process is stable if it is only influenced by common causes of variation.

You don't actually need to know the process specifications to determine process stability but you must know the specifications to determine capability.

The outcome of a Process Capability study is a single metric, which provides an indication of the ability of a process to consistently provide output which is within required specifications.





ADVANTAGES:

1. Quicker inspection method.
2. Economical.
3. Used in mass production.
4. Need semi skilled operator.
5. This system features online SPC analysis that means it provides immediate indication for correction in process, thus providing reduction in scrap, cost, and time.

DISADVANTAGES:

1. PC is required for implementing the SPC feature in this system.

VIII APPLICATIONS:

1. In automobile and mechanical industry.
2. For measurement and analysis of different mechanical gears with different diameters.
3. For checking of process stability in a workshop.
4. For trend monitoring of a process during production.
5. To suggest if change of tool is required i.e. to indicate tool wear.
6. In Military and Defense applications for high accuracy requirements.

IX CONCLUSION:

The PC based Gauging System can be viewed as an integration of two processes involved in manufacturing industry, i.e. physical measurement of a part's dimensions and detail analysis of the measured dimensions using Statistical Process Control techniques.

The specialty of this system is that it offers high flexibility and accuracy. Almost all kinds of automobile parts can be measured using this system, once the appropriate mechanical fixture is available.

LPC 1778 was chosen as it has large no. of input output and can be used for time-critical applications due to it's 32 bit timer.

Due to high accuracy needs, LVDT from Mercer with a measuring range 4mm and sensitivity 70mV/V/mm is used. AD698 IC which is a complete, monolithic Linear Variable Differential Transformer (LVDT) signal conditioning subsystem is used in conjunction with LVDTs to convert transducer mechanical position to a unipolar dc voltage with a high degree of accuracy and repeatability.

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We would like to thank Mr. Nitin Vaidya (NUTEK Pvt. Ltd., Pune) Guide and Mentor of the project for providing insight and expertise for this project work.

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