Quality Assurance and Manufacturing Processes related to Steering Column Components

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Abstract - *Quality assurance (QA) in manufacturing is essential to prevent defects, ensure product consistency, and comply with safety standards, ultimately reducing costs and enhancing brand reputation. By implementing proactive, step-by-step procedures throughout the production cycle, manufacturers avoid costly rework, minimize waste, and maintain high levels of customer satisfaction. This paper contains insights of Quality Assurance, Control and manufacturing processes gained during my internship period at ICON Precision Engineering Company. The paper covers elements of Quality Assurance and Manufacturing processes like Turning on CNC, Drilling, Milling on VMC, Spline Rolling and Cylindrical Grinding Processes.*

***Key Words*: Quality Control, Quality Assurance, MSA, Statistical Process Control Parameters, Quality Control Tools, Inspection tools, CNC Turning, Grooving, Facing, Centering, VMC Milling, Drilling, Tapping, Boring and VMC Tools.**

1. INTRODUCTION

Quality in manufacturing means consistently checking parts that meet or exceed customer expectations and specifications, achieved through controlling processes from inward of material to dispatch, minimizing defects, reducing waste, and ensuring reliability, performance, and safety through Quality Assurance (QA) and Quality Control (QC). It's about achieving a predictable, controlled process that delivers "right first time" products, building brand reputation, and gaining a competitive edge. Production processes form the backbone of manufacturing and service industries, transforming raw materials, information, and resources into finished goods and value-added services. Manufacturing processes taking place on workpiece adhere to the Process Flow Diagram prepared by the respective company from inward of raw material to the final dispatch of finished product. For instance, Inward of raw material with specified diameter. Production department gives raw material issue slip to store for issuing required quantity of raw material from the store. In incoming inspection raw material diameter is checked and workpiece visually checked to see for any dents. Ultrasonic test carried out to check for cracks or pores and chemical testing of raw material takes place for chemical composition. Once the results of all these tests come correct, raw material goes to store for production. On Automatic Cutting Machine material is cut to length as given on control plan drawing. In cutting, diameter is not changed. Only length of rod is reduced. For safer side, length of rod kept on control plan is 1.5 to 2mm greater than that on the customer drawing to account for extra material removal. On the subsequent CNCs Facing, Centering, Turning, grooving operations take place after which spline Rolling or Thread rolling takes place. Cylindrical Grinding Process carried out on some Shafts. Some jobs are black odised before dispatch. After all the processes jobs undergo final inspection after which they are dispatched.

1.1 Quality Control and Quality Assurance

A] Special Characteristic Parameters

Special characteristics or Critical parameters whenever a Shaft is produced by a given customer drawing include: -

- Threads: Threads are checked as critical dimensions because they are fundamental to the assembly, structural integrity, and functionality of mechanical components. Minor deviations in thread pitch, diameter, or angle can lead to, or result in failed assemblies. Incompatible threads (mismatched sizes) will not fit together or will not tighten properly.

- Spline: Ensuring Precise Fit and Assembly. Splines must fit together with specific tolerances to allow for smooth assembly and disassembly.

- Grinding: Grinding is used to achieve extremely tight tolerances and superior surface finishes that earlier processes like turning or milling cannot achieve. Part Functionality & Assembly: Grind surfaces must fit perfectly within an assembly, and variations can affect the functioning of bearings, hydraulic systems, or engine components.

- Hobbing: To Ensure They Fit and Function Gears must mesh perfectly. If the teeth are too thick, too thin, or the wrong shape, the gears will not work, or they will break.

B] Measurement System Analysis

Measurement System Analysis evaluates how good measurement system (Measuring instruments; Vernier Caliper, Gauges, Micrometer, Operator skill, part being measured, measurement method) is. Ensures that variability in measurement falls within acceptable tolerances.

Elements of MSA: -

1) Accuracy: How close measurement is to true value.

2) Bias: Measured and true value difference.

3) Linearity: Checks if bias remains same across all measurement range.

4) Stability: Measurement system gives same results with time. Same part, same instrument, same operator, different time.

5) Accuracy: How close repeated measurements are to each other.

6) Repeatability: Variation when same operator measures same part with same instrument multiple times to get multiple readings.

- Gauge Repeatability: Same operator measures same job with same gauge multiple times.

7) Reproducibility: Variation due to different operator. Same part measured by different operators.

- Gauge Reproducibility- Different or multiple operators measuring same job.

C] 7 Quality Control Tools

1) Check Sheet: Checks if All process parameters are filled correctly.

2) Fish Bone Diagram: Checks for Root cause of Defects.

3) Control Chart: Controls stability of process. Plotted points should lie b/w UCL (Upper Control Limit) and LCL (Lower Control Limit).

4) **Histogram: -**

   X Axis: Diameter Range

   Y Axis: No. Of Shafts

5) Pareto Chart: Bar graph that identifies defect causes.

6) **Scatter Diagram:** Used in quality control to analyze the relationship between two variables, typically a potential cause (independent variable) on the x-axis and a defect or effect (dependent variable) on the y-axis.

7) Process Flow Diagram: Sequence of processes from inward of raw material to dispatch of products. Represented with Boxes and Arrows.

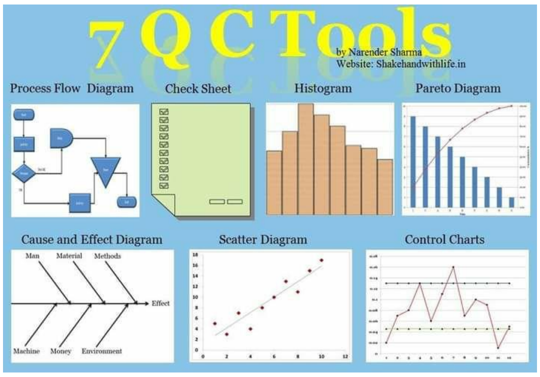

Fig 1: Quality Control Tools

D] Statistical Process Control: -

- Catches problems in process during production before wrong parts are produced.

- If the readings of diameter of upper shaft when plotted on control chart falls above UCL and below LCL, the process needs to be corrected to prevent if from falling below LTL and above UTL and becoming unstable.

- If the readings of diameter of upper shaft when plotted on control chart lie between UCL and LCL, then the ongoing process is stable. Parts lie b/w UTL and LTL.

- Cp: Process PotentialMeasures if the process spread fits within the engineering tolerance (Upper Specification Limit – Lower Spec Limit). Cp>= 1.33 For process to be stable.

- Cpk : Process Capability IndexMeasures actual capability of process by considering proximity of Process mean to nearest specification limit. Cpk > 1.67 for process to be stable.

E] Inspection Tools:

1) Attribute Gauges: Go no go principle, pass, or fail.

   Principle of Attribute Gauges: -

   Job should go through 'go' part of gauge.

   So, job accepted.

   Job should not go through 'No go' part of gauge.

   If it goes through 'No go' part of gauge,

   Job is rejected.

Types Of Attribute Gauges: -

1) Plain Plug Gauge: To check Internal Diameter.
2) Thread Plug Gauge: To check Internal threads.
3) Thread Ring Gauge: To check Outer diameter threads.
4) Plain Ring Gauge: To check Outer Diameter.
5) Width Gauge: To check slot.
6) Snap Gauge: To check Outer diameter.
7) Spline Gauge: To check for Spline.

2) Variable Gauges: To measure dimensions of parts produced and verify if they are in acceptable tolerances according to customer drawing.
Types of Variable Gauges:
1. Micrometer: To measure Outer Diameter. Least count: 1 Micron

Fig 2: Micrometer

2.Vernier Calipher: To measure OD/ID, Depth, Groove Diameter, length
Least Count: 10 Micron

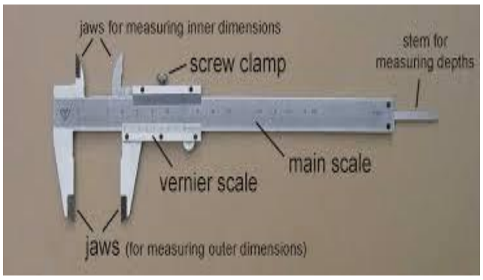

Fig 3: Vernier Caliper

3.Digital Height Gauge:
To measure vertical distances or length.
Least count: 10 Micron

Fig 4: Digital Height Gauge

4. Air Plug Gauge: Used to check the job after Grinding operation. Why?
1) For low tolerances 2) For low cycle time

Fig 5: Air Plug Gauge

5. Bench Centre: Inspection tool used to check circular runout of the Shaft as per given customer drawing.

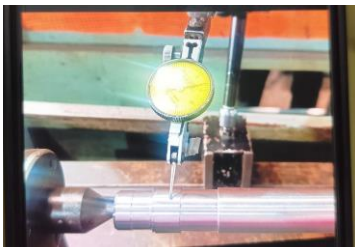

Fig 6: Bench Centre

F] Types of Inspection

1.Inward Inspection: Checks diameter of raw material, chemical testing of raw material for chemical composition, ultrasonic test to detect cracks or pores inside raw material.

2. In process Inspection: Checks the dimensions of parts as they are produced with micrometer, vernier, height gauge, taper checking by placing ball, checking pin diameter to check for spacing b/w teeth created by hobbing to make sure that they fall within acceptable tolerances. Data maintained in Setup Approval Report.

3. Final Inspection: Checks the parts before they are dispatched through go and no-go gauges. Visually checked for any dents, burrs etc.

2. Manufacturing Processes

1] CNC Turning Center

Fig 7: CNC Machine

Operations performed on CNC include:

a) Facing: The process of machining the end of a workpiece to create a flat surface perpendicular to the axis of rotation.

b) Centering: Drilling a small conical hole (center hole) into the end face to establish a precise center point for holding the workpiece between centers (revolving and dead centers) on subsequent CNCs.

Fig 8: Facing and Centering

c) Turning: Reducing diameter of workpiece. The workpiece is clamped in a chuck (dead and revolving centers) and spun at high speeds while a single-point cutting tool moves linearly (axes X and Z) to shape it. CNC turning is a precise, subtractive machining process where a workpiece rotates on a CNC lathe while a stationary cutting tool removes material to create cylindrical parts with high accuracy.

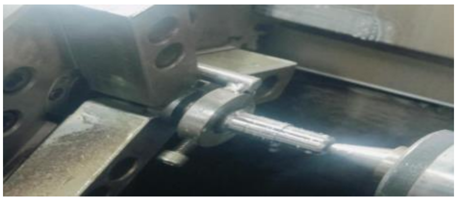

Fig 9: Turning

Fig 10: Workpiece after Turning

d) Straight Turning: Straight Turning in CNC is a fundamental machining process where a cutting tool moves parallel to the axis of a rotating workpiece to reduce its outer diameter uniformly. It is used for producing precise cylindrical components like shafts and pins, often requiring both roughing and finishing passes to achieve required dimensions and surface finishes.

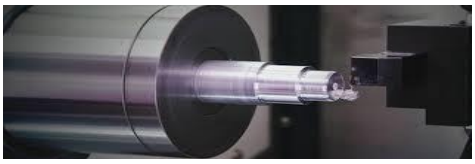

Fig 11: Straight Turning

e) Taper Turning: Taper turning in CNC is a machining process that produces a conical, uniformly angled surface by gradually changing a workpiece's diameter along its length. Morse tapers, tools, and tapered shafts.

Fig 12: Taper Turning

f) Grooving: Grooving in CNC machining is a turning operation that cuts narrow, precise, and often deep, rectangular, or specialized cavities (grooves) into a workpiece's external, internal, or face surfaces using a CNC lathe.

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1. **Hobbing**

Gear hobbing is process of generating gear or generating teeth on shaft or workpiece by means of cutter called hob. Teeth cutting on shaft involves three basic motions. Hob and blank or shaft has rotating motion and third one is radial advancement of hob. Blank is first moved in towards rotating hob until proper depth is achieved. Hob cutter fed across the face of shaft until teeth are complete. Both hob and gear rotate during process. The hob moves longitudinally along the length of the shaft.

Fig 13: Hobbing

2. **Cylindrical Grinding**

Cylindrical grinding is a high-precision machining process that uses a rotating abrasive wheel to remove material from a rotating cylindrical workpiece, achieving superior surface finish and strict dimensional tolerances. It is primarily used to grind external (OD) or internal (ID) diameters, tapers, or cams on shafts, pins, and bearings. In a typical Cylindrical Grinding Machine, the workpiece undergoes rotation along its axis, supported by two centers. The high-speed rotation of the grinding wheel serves to grind both centers on the workpiece's axis, resulting in the creation of a polished and even surface. OD grinding is grinding occurring on external surface of an object between the centers. The centers are end units with a point that allow the object to be rotated. The grinding wheel is also being rotated in the same direction when it comes in contact with the object. This effectively means the two surfaces will be moving opposite directions when contact is made which allows for a smoother operation and less chance of a jam up.

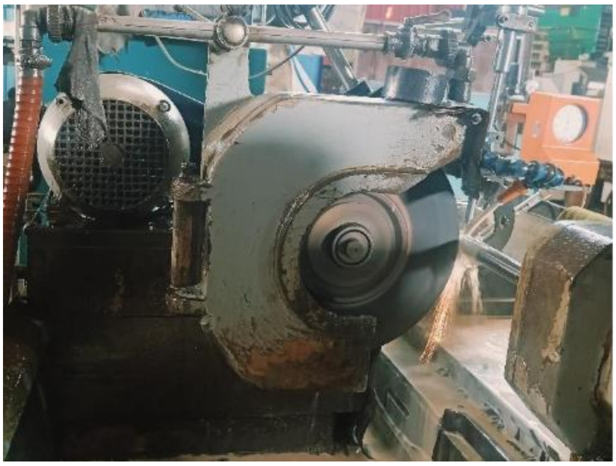

Fig 14: Grinding

3. **Spline Rolling/Thread Rolling**

Thread rolling/Spline rolling is done by using pair of circular rolls with the identical threads or splines to transfer work material through plastic deformation rather than cutting or material removal. Workpiece or shaft placed between fixed and movable circular rolls that has grooves corresponding to target threads. Under pressure workpiece rolled between two rolls , resulting in thread pattern/spline pattern being pressed into workpiece without production of chips. It is metal forging technique. Types of die used are flat rolls and circular rolls. Rolls used in these images are circular rolls.

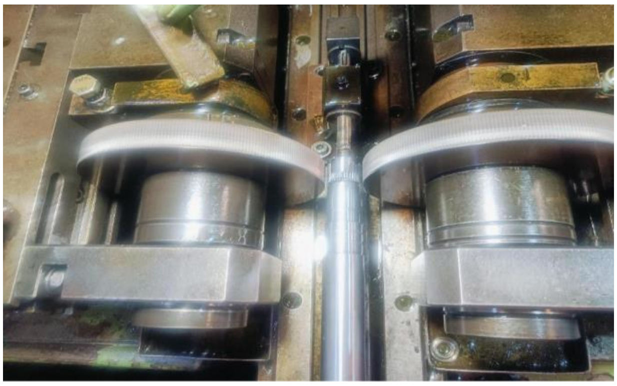

Fig 15: Thread & Spline Rolling

4. **Blackodising**

Blackodising is a process that forms a corrosion-resistant coating on ferrous metals through a chemical reaction when immersed in a hot alkaline salt solution. This is done to prevent rust formation.

2] Inserts in CNC

CNC inserts are small, replaceable cutting tools used in CNC machines to remove material from workpieces. These inserts are designed to be easily interchangeable, allowing operators to quickly replace worn or damaged cutting edges without changing the entire tool holder

1. CCET

Fig 16: CCET

2. VNMG

Fig 17: VNMG

3. APMT

Fig 18: APMT

4. TNMG

Fig 19: TNMG

3] VMC

A VMC machine is short for Vertical Machining Center. Where the spindle, which is the axis that holds the cutting tool, is oriented vertically (i.e. up and down). The workpiece sits on a table below, and the cutting tool comes down on it. Bench wise or fixture holds the workpiece on VMC table which moves in X, Y axis. Cutting tool moves up and down along z axis. There are three axes in VMC. Workpiece remains stationary. Movement of cutting tool takes place. VMCs use multiple tools for different operations. The Automatic Tool Changer (ATC) swaps tools automatically, reducing downtime and improving productivity.

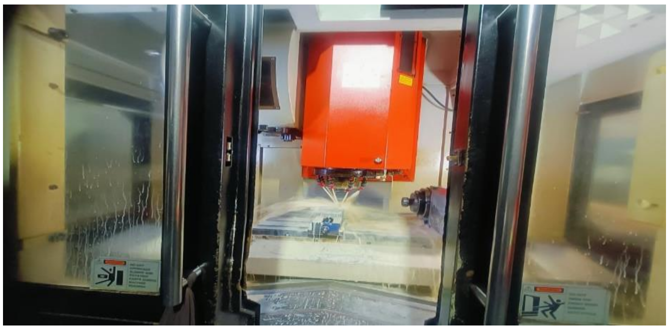

Fig 20: VMC Machine

Operations performed on VMC include:

a) Milling: Milling is the process of machining using rotary cutters to remove material by advancing a workpiece into the cutter. This may be done by varying directions. Milling is used to create slots, achieve smooth surface finish and for shaping the material as and how required.
b) Drilling: Drilling is process of process of producing round holes in a workpiece with the use of multipoint cutting tool called drill. Drill is rotary cutting tool with flutes for passage of chips and for admission of coolant.
c) Boring: Machining process that enlarges pre drilled hole for achieving high accuracy, finish and smoothness. Tool used is drill bit.
d) Tapping: Tapping is a machining process that creates internal threads in a pre-drilled hole, allowing bolts or screws to fasten components securely. Utilizing a tool called a tap—made of high-speed steel or carbide—the process involves rotating the tool into the hole to cut or form threads.

4] Tools used in VMC

1. Drills
a) U Drill: U drill uses inserts to drill hole of given depth (true coolant) in one cut. Rough drilling takes place. It is used for high-speed drilling with low cycle time.

Fig 21: U Drill

b) Centre Drills: Centre drill is used in a VMC (Vertical Machining Centre) primarily to create an accurate, rigid starting point for subsequent drilling operations. Because of its short, thick, and rigid construction, it prevents larger twist drills from “wandering” or deflecting on the material surface, ensuring precise hole positioning and improved surface finish. The rigid, short tool creates a small conical hole that guides the tip of the follow-up drill, ensuring it starts exactly where intended, especially on uneven or hard surfaces. Significantly improves the positional tolerance of holes, which is crucial for CNC machining.

Fig 22: Centre Drill

c) Twisted Drill

Twist drills are used in Vertical Machining Centers (VMCs) primarily for their superior capability to create, enlarge, and produce high-quality cylindrical holes efficiently in a single operation. The spiral flutes (grooves) allow chips to exit the hole, preventing clogging during deep drilling. High Productivity: Designed for high-speed, automatic, and precise hole-making, they maximize metal removal in a minimal amount of time.

e) Flat drills:

Flat drills are used in Vertical Machining Centers (VMCs) primarily to create flat bottomed holes in a single operation, eliminating the need for secondary, time-consuming finishing passes. They are essential for precision applications, such as counterboring, drilling on angled surfaces, or tapping blind holes.

Fig 23: Flat Drill

e) Step Drill: Step drill can drill holes of various diameters, save time, and reduce the need to carry multiple drill to individually drill holes of various diameters on the same workpiece.

Fig 24: Step Drill

f) Core Drill

Core drills are used in Vertical Machining Centers (VMCs) primarily to create large-diameter, deep, or precise holes efficiently in hard materials. Core drilling removes cylindrical, solid samples from hard materials unlike chip removal in twist drill. Drill has teeth on it.

Fig 25: Core Drill

Through Coolant Drill: Through-coolant drills (coolant-fed) are used to significantly increase productivity, extend tool life, and improve hole quality by delivering coolant directly to the cutting edge, even in deep holes. They eliminate the need for frequent peck drilling, allow for higher cutting speeds, and prevent chip clogging. With this drill in one cut entire material is removed and in one go accurate diameter hole is drilled.

Fig 26: Through Coolant Drill

- **Reamer**

Reamers: Reamer is used after drilling to achieve very high and smooth surface finish for drilled holes. It is used for low tolerances. For instance if a hole of 14 mm diameter is to be drilled accurately, first drill will be used for drilling hole of 13.75 mm which removes large amount of material. After drilling reamer will remove 0.25mm of material to get accurate hole diameter of 14mm.

5] Endmills in VMC

1) Flat Square Endmill: A flat square endmill has a flat cutting end with sharp corners (90° edges). Cutting straight slots or grooves in the workpiece. Example: keyways, channels, or rectangular pockets. Removing material inside a cavity with flat bottoms. Cutting the perimeter or outline of a part for side milling.

Fig 27: Flat Square Endmill

2)Ball Nose Endmill: A ball nose end mill has a rounded tip instead of a flat end. The cutting edge is spherical at the tip, which makes it ideal for curved surfaces. It is used for profile milling. Cutting complex 3D shapes. When a cavity or pocket has a rounded bottom, a ball nose can produce it directly.

Fig 28: Ball Nose Endmill

3)Tapered Endmill: To produce tapered holes. To create tapered slots.

Fig 29: Tapered Endmill

4)T Slot Cutter: T slot cutter used to cut T slots in workpiece.

Fig 30: T Slot Cutter

6] Taps in VMC

1) Straight Taps: Straight flute taps (also known as hand taps) are the standard tool for creating internal threads in pre-drilled holes. Because their flutes run straight along the axis, they do not automatically eject chips, ideal for threading through holes.

Fig 31: Straight Tap

2) Spiral Tap: Spiral fluted taps draw chips out of the hole, perfect for threading blind holes.

Fig 32: Spiral Tap

3) Form Tap: Form taps (or roll/fluteless taps) create internal threads by
displacing material rather than cutting it, producing stronger, chip-free
threads. They are used for threading holes in Aluminium material.

Fig 33: Form Tap

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REFERENCES

[1] Operated as an Intern with primary focus on Quality Assurance and Manufacturing Processes related to Steering Column Components at ICON Precision Engineering Company located at Chikhali, Pune.

[2] Statistical Quality Control and Quality Management by author R.C. Gupta

[3] Machining and Machine Tools- A.B. Chattopadhyay

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