Metrology
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Lecture – 40
In-Process Gauging and Control

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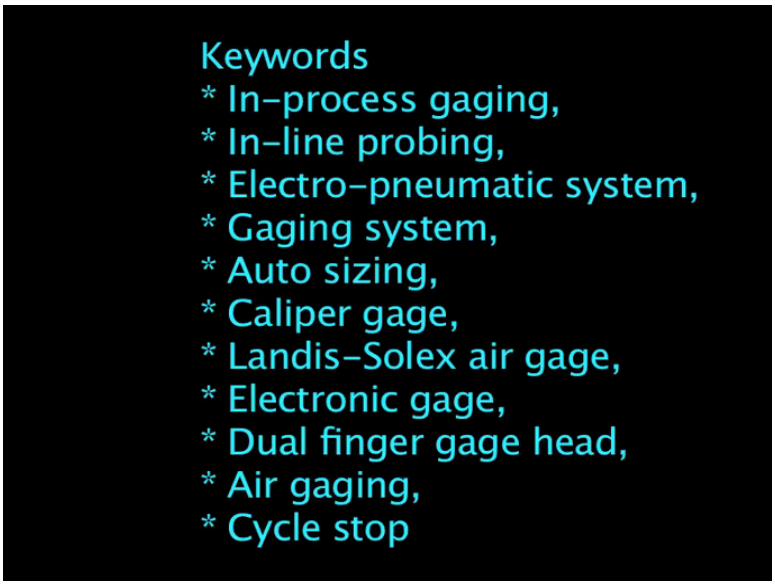

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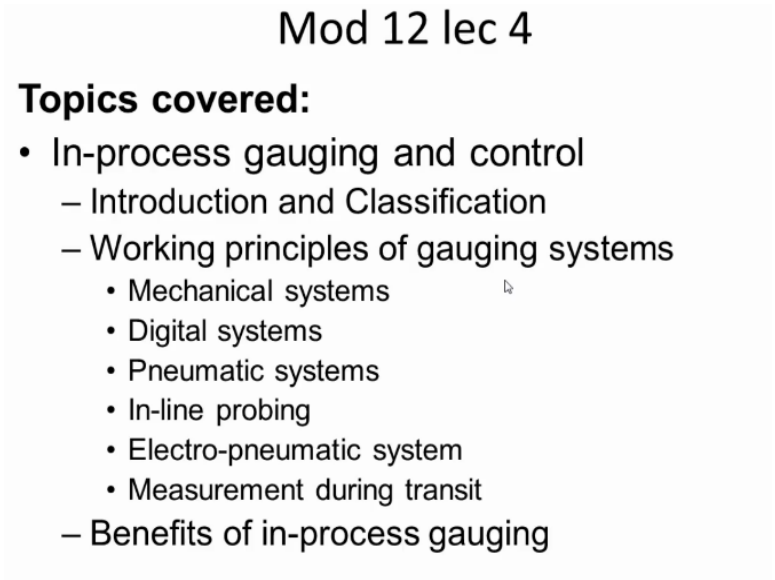

I welcome you all for the lecture series on Metrology, now we will start module number 12, lecture number 4. In this lecture, we will be covering in-process gauging and control, which includes introduction to the in process gauging and how the in-process gauging systems are classified.

A then we will be discuss about the working principles of various gauging system, in which we will we will be studying about mechanical gauging systems, digital systems, pneumatic systems, in-line probing and electro pneumatic system and measurement during transit. Finally, we will be discussing about various benefits that can be obtained by in-process gauging.

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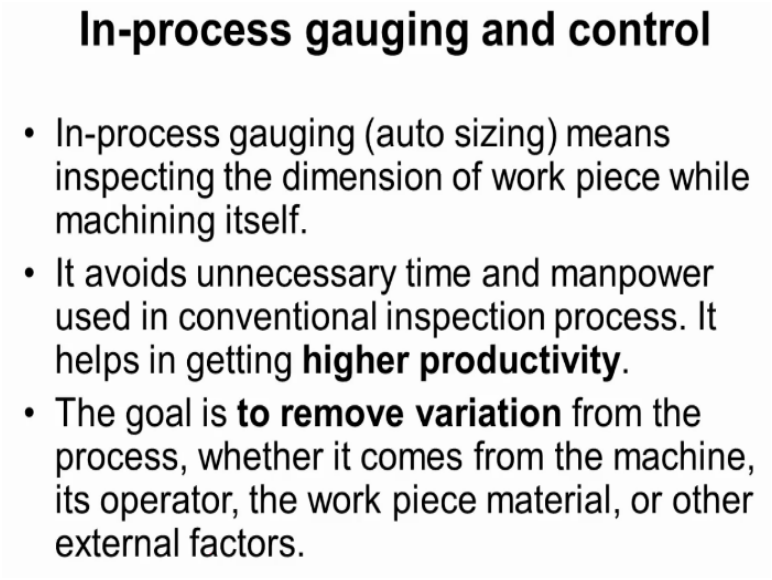

Now let us try to understand what is the meaning of in-process gauging and control. In process gauging in other words it is also known as auto sizing, it means inspecting the dimension of the work piece while machining itself. In the normal process, what we do, the work piece is machine and the machine is stopped to check whether the correct size is achieved or not that means if we take the example of a turning process, after giving few cuts, the operator will stop the machine, it stop the rotation of the work piece.

Then, we will take the appropriate instrument like micrometre or vernier caliper and then he will check what is the diameter that is obtained. If the size is okay, then he will remove the work piece and he will put new raw material. If the size obtained is not to the correct size or if there is extra material will stop the machine and it will give few more cuts, so in the process, lot of time is wasted and the cycle time will increase.

So to avoid the unnecessary time that is non-productive time and the effort of manpower used in conventional inspection process, this in-process gauging is used. It helps in getting higher productivity. The goal of in process gauging is to remove variation from the process. In the conventional inspection process, the sizes of the work piece may vary from work piece to

work piece, whereas the case of process gauging, that variation can be minimized. Now these in-process gauging systems are classified as given below.

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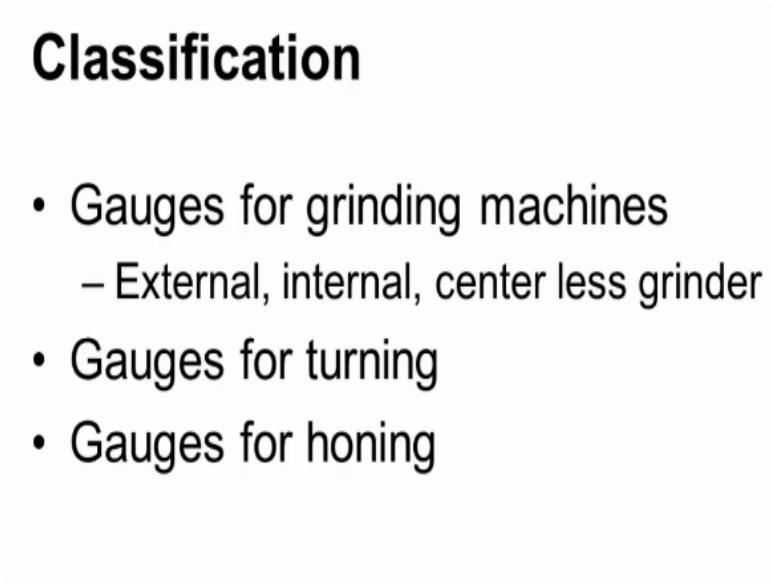

In-process gauging systems for grinding machine including the external gauges, gauges for internal grinding and gauges for center less grinding process and the gauges for turning process are also available and gauges for honing process are also available.

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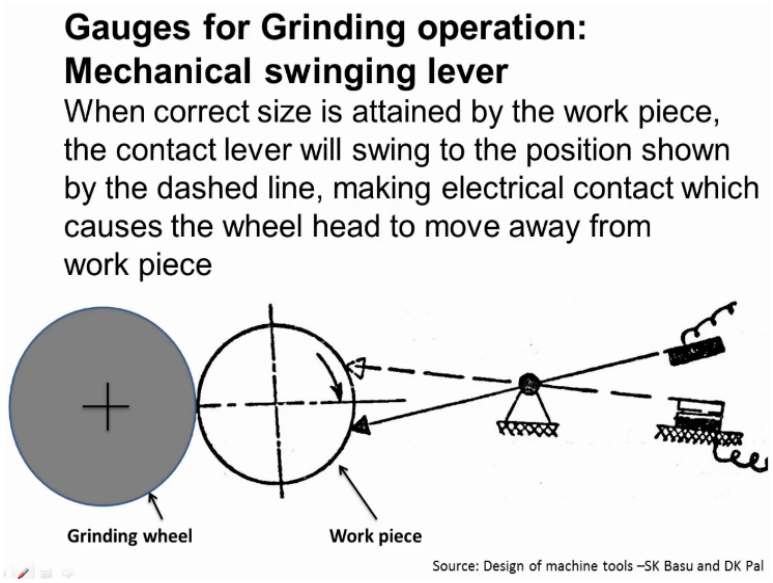

Now let us study the in-process gauges for grinding operation, so this picture shows a mechanical swing in the lever, this is the grinding wheel and we have work piece, which is rotating, both are rotating in the proper direction and there is a pivot pitch, which carries this lever, when the correct size is obtained by the work piece, the contact lever will swing to the

position shown by the dashed line, so this is the initial condition of the swinging lever and the correct size reached.

The lever swing to the position shown by the dashed line and when it swings, it makes electrical contact, this contact will move and makes a contact, which causes the wheel head to move away from the work piece that is when the work piece attains the correct size, the wheel head moves back and the machine process stops.

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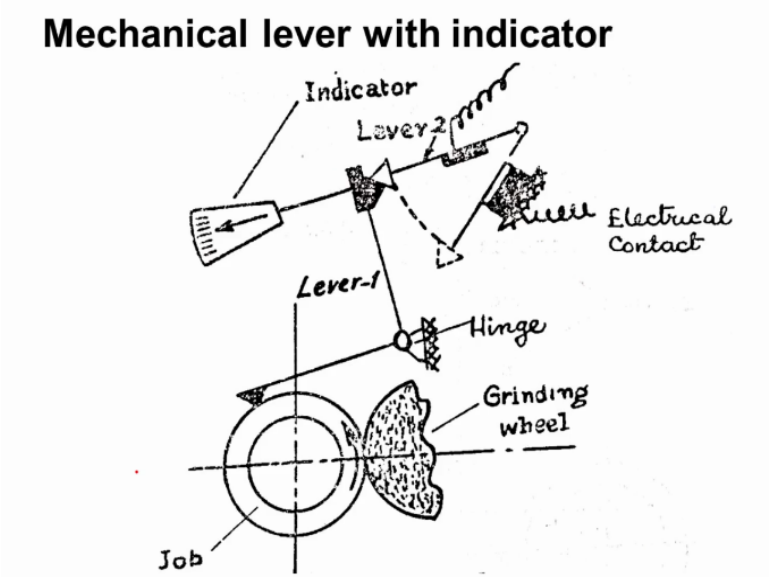

Now this diagram shows another system wherein there is a mechanical lever with indicating the system, this is the grinding wheel and this is the job, w is to ground and there is a probe or stylus, which is in contact with the rotating work piece and there is a hinge and we have this lever 1, see when the grinding process continuous like this, the diameter goes on reducing and the stylus will be in contact because of the spring force and this lever 1 will move to the new position shown by this dashing line.

So this indicator will show the change in this size of the work piece diameter, the correct size or reset size is reached, this lever will move in this direction and the lever 2 will fall down and it makes this contact will make a contact over here and because of this, a solanoid will be activated, which will withdraw the grinding wheel head in this direction and measuring process stops, this is how the in-process gauging in mechanical lever indicator system works.

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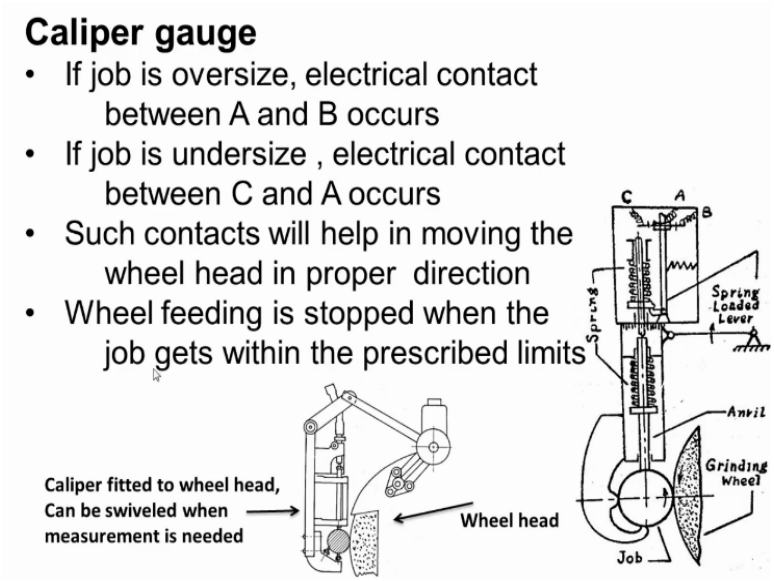

Now we have another type of system, which is calibre gauge, we can see in this diagram, we have the grinding wheel and then we have the wheel head. Now this caliper system, this is the work piece, the caliper system, which is fitted to the wheel head and this caliper can be swivelled in this direction and whenever measurement is required, this can be spin and it will be in this position, whenever the measurement is not required, it can be removed from this position.

Now this picture shows the details of the caliper gauge, this is grinding wheel and this is the work piece to be ground and this is the caliper and here there is a anvil, which is in-contact with the work piece and this spindle will move in this vertical direction, so this anvil will be in contact with the work piece due to this spring force acting in this direction.

So initially, when the diameter is moved, when there is excess material in the desired size, so this is desired size and this is the raw material varying extra material is there, which is to be ground. The angle will be in contact to the periphery of the work piece. So if the job is oversize that is extra allowance is there, when the job is oversized, electrical contact between A and B occurs, so electrical contact between A and B occurs and then the wheel head is moved in the forward direction.

And then grinding continues. If the job is undersized, which is less than job becomes smaller than the desired size, electrical contact between C and A occurs and a solanoid will be activated and wheel head is withdrawn, such contacts that means the electrical contacts will help in moving the wheel head in proper direction that means when there is enough material

to be ground, the wheel head will move in the forward direction. When the work piece becomes equal to the desired size or less than the desired size, the wheel head is withdrawn.

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- Component size range:- 10 mm -1000 mm
- Accuracy 0.0025 mm
- Narrow design for use with **crank grinding** steady rest.
- Sealed transducer
- Off-set tips for **oil holes**
- Replaceable Carbide tips
- Profile Shoes

The wheel feeding is stopped when the job gets within the prescribed limits. Now we can see the commercially available caliper gauge, this is the arrangement, this is the clamp for clamping this caliper gauge to the wheel head and this is the caliper, there is a carbide point edge in contact to the work piece and this is the spindle, which will move in this direction depending upon the size of the work piece.

And here there is an electrical cable, which will go to the electrical contacts, so the caliper gauges are available from 10 mm to 1000 mm range, accuracy that means the work piece accuracy will be of 2 micros or 2.5 microns when we use the caliper gauges like this and narrow design for use with crank grinding study rest and the transducers are sealed since the gauges are to be used on lot of cooling and used or properly sealed offset tips are provided for oil holes and the gauges contains replaceable carbide tips and profile shoes are also available.

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Small diameter gauging:
Down to 2 mm diameter, and up to 1000 mm.
Easy to adjust

Commercially the caliper gauges are available for very small diameter gauging the systems available for measurement of 2 mm diameter and up to 1000mm. In this picture, we see the caliper gauge in vertical setting and work piece mounted between centres and grinding and the caliper gauge fitted in the head and also see the arrangement of setting of the caliper gauge. In this picture we can see the horizontal mounting of the caliper gauging using the adjustment facility provided we can adjust the gauge to the work piece.

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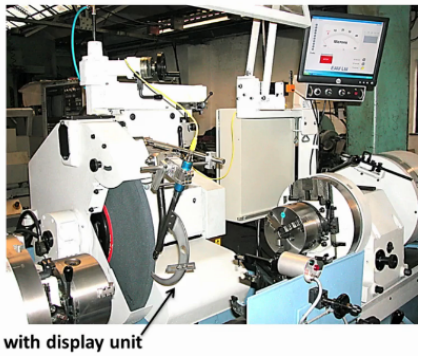
- Clear display of size and set points
- **Sealed transducer** for maintenance free operation
- Can display:- Component count, wheel dressing alarm, wheel balance, wheel speed, coolant temperature, time and date display.
- Change from imperial to metric.
- Multiple diameter display



Caliper gauge with display unit

Now we can see a caliper gauge with display unit we have monitor placed over here there is a clear display of size and set points this will also show the digital and analog display and we can see sealed transducers for maintenance free operation can display component count wheel dressing alarm wheel balance wheel speed coolant temperature time and date display change

from imperial to metric as when needed multiple diameter display is also possible we have to use the multiple gauges so that multiple diameter display is possible.

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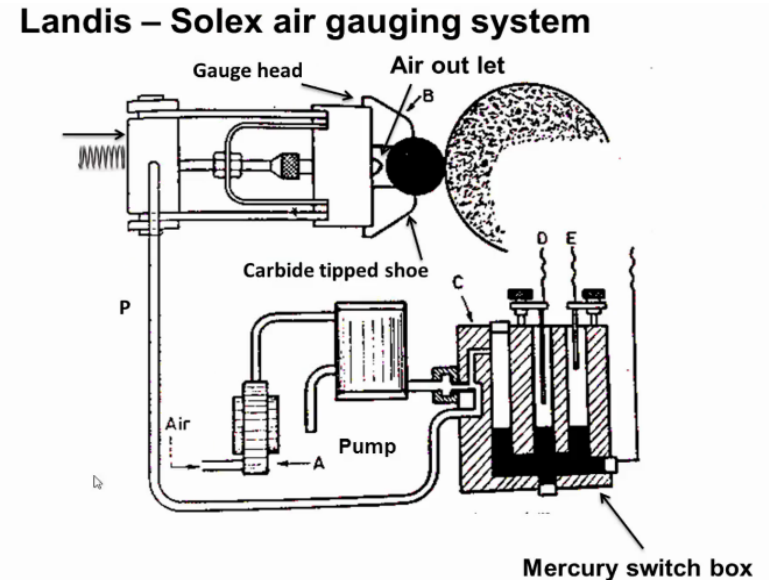

Now this picture shows the schematic arrangement of Landis Solex air gauging system this is the grinding wheel this is work piece and then we have gauge head and carbide tipped shoes are contact with the rotating work piece and between the shoes we have air outlet air is escaping from the outlet the amount of air escaped depends upon the condition gauge head that dictates the air that is escaping so the pressure in the line depends upon the gap of the nozzle and work piece and there is a pump, which will pump the air.

We will get the compressed air will move in the direction and compressed air will escaping from the nozzle and the compressed air it also enters in to the switch box in the switch box we have 2 electrical contacts D and E are set on different height the height settings depends upon the size of the work piece desired.

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- If air is escaping from a pressure line, the pressure in the line (P) is affected by nozzle conditions at the outlet through which it is escaping
- This change in pressure is used to change the level of mercury in a mercury switch box, thereby closing contacts (D and E) which control grinding wheel feeding.
- **Air pressure of 0.15 bar** is supplied by a pump (A), to the caliper frame (B) which has two carbide tipped shoes that rest lightly on work piece. The air outlet is between these 2 shoes.

Now the working principle is shown here if the air is escaping from a pressure line the pressure in the line p is affected by nozzle conditions at the outlet through which it is escaping this change in pressure is used to change the level of mercury.

In a mercury switchbox thereby closing contacts D and E which control grinding wheel feeding air pressure of 0.15 bar is supplied by a pump A to the caliper frame B which has 2 carbide tipped shoes that rest lightly on work piece the air outlet is between these 2 shoes this is the air outlet placed between the 2 shoes.

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- As grinding proceeds, spring tension moves the **gage head** forward, thereby decreasing the gap between work and air outlet. Pressure thus builds in the air line (P) causing the mercury to rise in the switch box C
- At the end of roughing operation, the mercury touches the contact D. An electric circuit is then completed, a solenoid is energized and finish (slow) feeding starts.
- Grinding continues until finish size is reached, gap between air outlet and work further reduces increasing the pressure in the line (P), then mercury rises in the switch box and electrical contact at E occurs.

As grinding proceeds spring tension moves the gauge head forward thereby decreasing the gap between work and air outlet Pressure thus builds in the airline P causing the mercury to rise in switch box C at the end of rough in b operation the mercury touches the contact D an

electric circuit is then completed a solenoid is energized and finish slow feeding starts grinding continues.

Until finish size is reached gap between air outlet and work further reduces increasing the pressure in the line P then mercury rises in the switchbox and electrical contact at E occurs so when the size of the work piece approaches the desired size the builds up and mercury of the level raises and then the electrical contact will happen with contact E.

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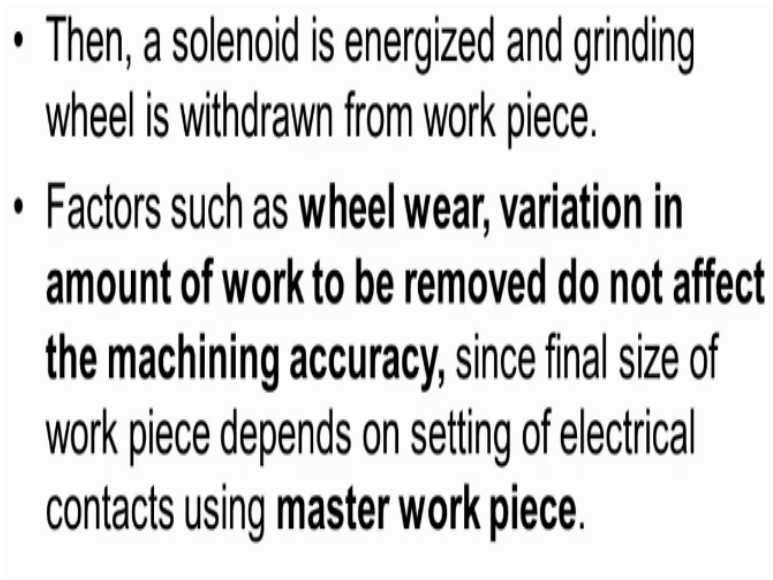

Then contact at E occurs the solenoid is energised and grinding wheel is withdrawn from work piece and machine stops factors such as wheel were variations in amount of work to be removed do not affect the machining accuracy since final size of work piece depends on setting of electrical contacts using E and D of master work piece.

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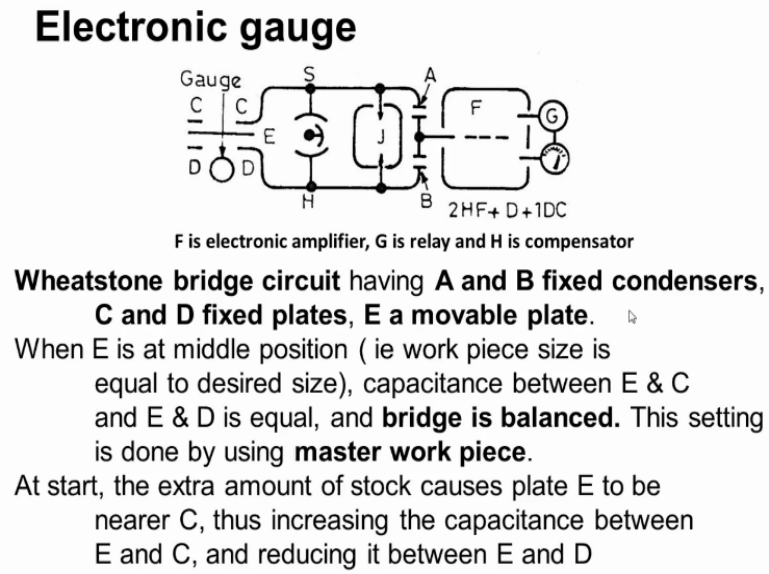

We will discuss another type of auto sensitive device based on electronic system we can see the diagram we have this is based on the wheat stone bridge circuit. In this circuit, we have A and B fixed condensers which means A and B fixed condensers C and D fixed plates and in between C and D we have movable plate E so this E will move up and down depending upon the size of the work piece then E is at the middle position that is work piece size is equal to desired size that means initial setting the system at a device.

By using a master work piece so we have to keep the master work piece in centre and we have to adjust the position of this plate E such that plate E is way between C and D at start the extra amount of stock causes plate E to be nearer see thus increasing the capacitance between E and D and reduced greater amount of gear due to the bridge circuit these 2 bridge is imbalanced.

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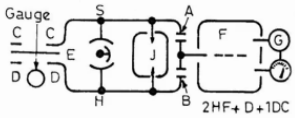
- When work piece reaches exact size, the bridge is balanced, and a **maximum current is permitted in the output stage** to operate a relay causing **withdrawal of grinding wheel**
- Any variations of temperature, humidity, ionization of air, frequency and voltage **act symmetrically on both sides of the bridge** and consequently have no effect on reading
- A **bracket for fixing the gauge** to machine is needed
- Final setting is done by means of a **compensator (H)** graduated in 0.0025 mm
- An accuracy of 0.001 mm can be repetitively maintained



Now when the grinding continues work piece reaches the exact size the bridges balanced and a maximum current is permitted in the output stage to operate a relay passing withdrawal of grinding wheel it is interesting to know that any variations of temperature humidity ionization of air frequency and voltage at symmetrically on both sided of the bridge and consequently have no effect on reading bracket for fixing the gauge to machine is needed.

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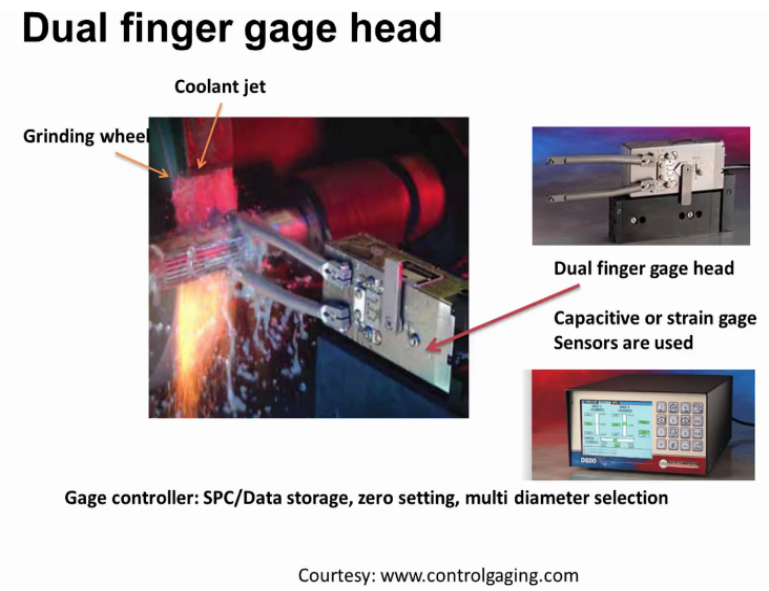

Final setting is done by means of a compensator H graduated in 0.0025 mm and accuracy of 0.001mm can be repetitively maintained. Now let us study type of ultra-sourcing system they have dual finger gauge head the diagram shown here this is the body of the imaging head houses the transducers either capacitive or strain gauge sensors are used in the system and 2 fingers are the these 2 fingers remain contact with the work piece which is being ground as the diameter reduces due to the continued reading.

The fingers always in the contact with the work piece because they spring board is active and since the fingers move closer in the capacitance are strains will be changed and electrical character is supplied to the inlet the display the size and correct size is desired work piece is reached an relay will be operated to the to withdraw gauging head work piece.

So in this photograph, we can see the work piece being ground and we can see the grinding wheel and we can see the coolant jet and then the fingers which are in contact with the work piece and the gauge controllers are provided with the gauge head for data storage and for zero setting a multi diameter selection gauging is also possible by using the multiple finger sets.

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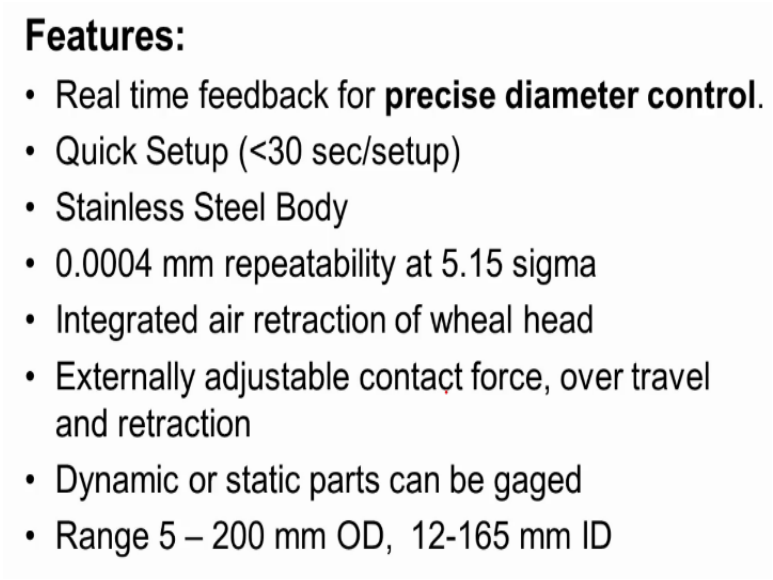

Now what are the features of the fingers of the auto facing device to precise diameter control is possible and real time control is possible and setting the head around the halt minute per set up stainless steel body is used, so that complete set up corroded due to the usage of water based coolants and repeatability of 0.0004mm is possible at 5.1 sigma level integrated air retraction system is available for interacting the wheel head and the correct size is reached.

Externally adjustable contact force over travel and retraction is possible this gauging system can be used as either dynamic or static parts the range of operation is 5 to 500 mm or OD 12 to 165mm ID.

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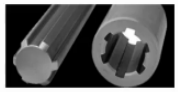
- For **plain outer diameters, interrupted outer diameters, inner diameters**



- Retraction amount: 2.5 degrees per finger (5.2mm using 118 mm length fingers)
- Retraction mechanism air pressure: 5 bar
- Weight: 1.6 kg

Applications:

- Armatures, Bearings, Bushings, Camshafts, Crankshafts, Cylinder linings, Drills, Impeller shafts, Motor shafts, Pistons, Reamers, Rotors, Splined shafts, Valves, Valve stems.

System can be used for playing outer diameters or interrupted outer diameters and this can also be used for gauging inner diameters so the retraction amount since that 2.5 degrees per finger so when the correct size is reached the fingers get retracted that means finger moves back and then the gauging unit is withdrawn retraction mechanism.

Air pressure is 5bar and total weight set is 1.6 kg and the system can be used for gauging armatures bearings bushings camshafts crankshafts cylinder linings drills impellers shafts motor shafts pistons reamers rotors splined shafts valves stems like this so it can be used for gauging in many industries.

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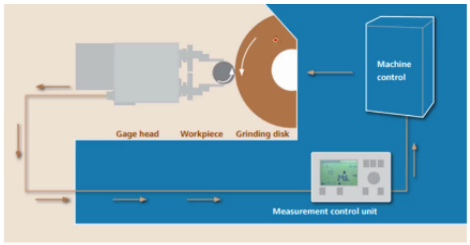
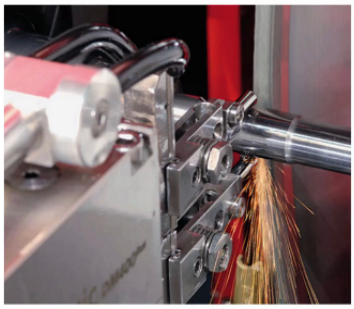
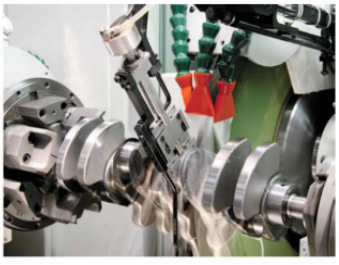




Outside diameter control application



Crankpin and journal control application

Now schematic diagram shows the grinding the wheel the work piece mounted suiting and then we can see the dual finger gauge head the signals from the gauge head will be sent to the

control unit by the measurement machine control unit when the desired size is reached machine control will send a signal to the wheel head for retraction.

We can see in this photograph the 2 fingers are contact with the work piece which is in a ground and we can see gauge head in action in a grinding wheel it is grinding the work piece and this is the gauge head. In this photograph, we can see the dual finger gauge head be used for in this photography auto sizing device that is calibrate gauge head can be used for the online inspections of crankshafts.

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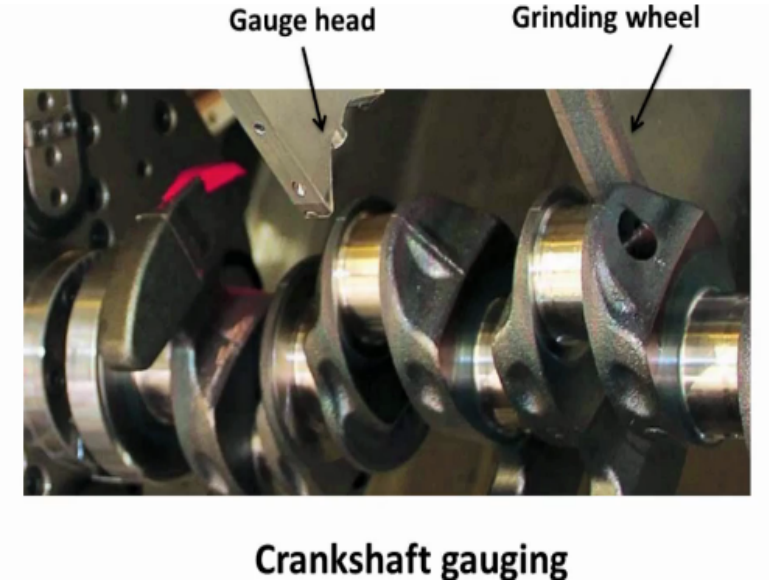

Crankshaft gauging

Here is the close view of crankshaft gauging, we have the grinding wheel and the gauge head we can see the shoes and the plunger which will be in contact with the form the surface.

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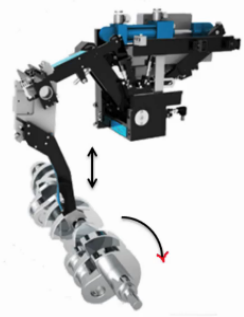
In-process measurement system for diameter and roundness

Diameter measurement:

Work piece diameter, mm	24-90	48-140
Stroke, mm	Upto 120	Upto 340
Measurement speed, rpm	Upto 80	Upto 80
Resolution , micrometer	0.1	0.1



Roundness measurement (at the end of machining)

Evaluation points	3600	3600
Resolution, micrometer	0.1	0.1
Measurement speed, rpm	Upto 60	Upto 60
Evaluation method	LSCI	LSCI

Now in this diagram we can see the arrangement for online gauging of the crankshafts the crankshafts will be rotating and the gauging head rotate along with the work piece that is crankshafts also it will move up and down because of the crank the gauging head will be mounted on the head there are some gauging heads process measurement systems measurement of diameter as well as roundness.

So one such gauging unit we can see in this photograph so the diameter measurement different models available in this models work piece diameter range will be 24 to 90 mm stroke of the gauging head will be up to 120mm measurement speed is up to 80rpm and resolution is 0.1micrometer the other stroke will be 340 stroke mm and measurement speed is up to 80 rpm and resolution micrometre is 0.1 and then at the end of the machining roundness of the ground.

And the work piece can be measured that is resolution evaluation of the first model 3600 points. Data points will be collected the measurement resolution is 0.1 micro meter measurement speed is up to 60 rpm and least square circle method is used for evaluation for assessing the ground ness.

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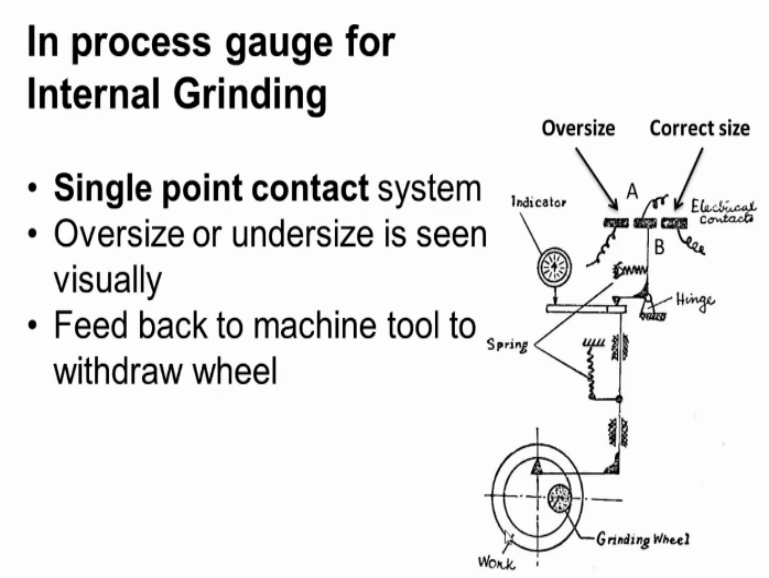

Let us discuss about the in process gauging system for internal grinding this diagram we can see the work piece the internal grinding this diagram we can see the work piece the internal pore is being ground this grinding wheel and this is this gauging point which has thin contact with bore which has single point contact system the styles is in contact with the bore and we can see the arrangement.

This link will same way as the grating perceives then gauging point will in contact with the inner surface of the bore and this is forced and the grinding proceeds the link will move up and the that is a hinge here and the B which is carrying the contact point will swing in the directions and it will makes contact and this contact with the electrical conduct and circuited will be closed and will be operated to withdraw the grinding wheel now.

When bore size is small that is there is grinding allowance will conduct the between A and B conducting the oversize the small and the contact between over here it indicates correct size is reached also when the grinding is rotates we can see the change in the diameter by reading this indicator.

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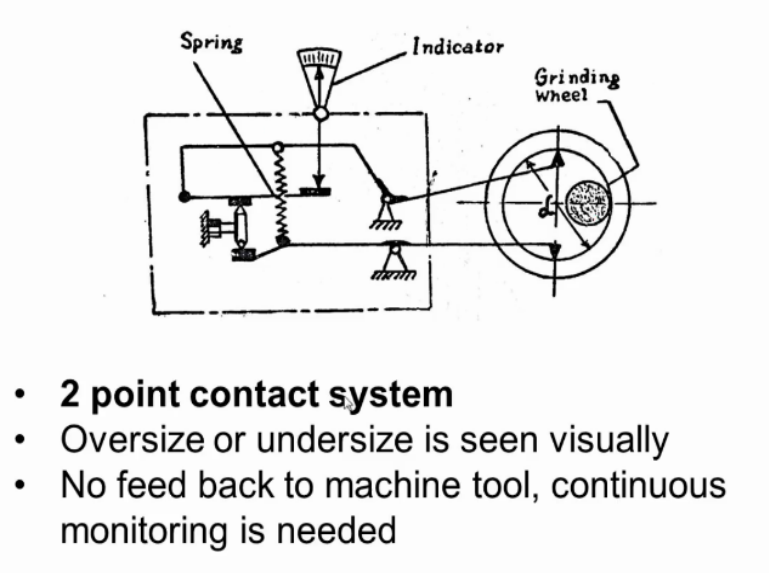

Now this schematic diagram shows 2 point contact system we can see the 2 points are in the contact to the internal bore of the work piece grinding wheel and because of the spring tensions in to stylus point is contact with the inner surface of the both and grinding the peruses the diameter getting enlarged and we can see the change in the diameter which is indicated by the dial indicator there is no feedback to machine tool continuous monitoring is essential in the system.

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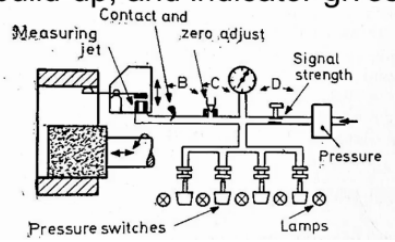
Pneumatic circuit for Internal grinding

- Air pressure is 0.6 to 1.5 bar
- 5 lamps to indicate different stages of grinding
- **Pivoted lever** with a pad makes contact with the bore of the component
- As the bore is enlarged during grinding, the lever turns about the pivot and the other end progressively restricts the outlet, causing the air pressure to build-up, and indicator gives reading



Now there are pneumatic systems available for gauging the internal bore that is gauging system for internal grinding the pneumatic pressure is 0.621.5 bar and we can in the diagram 5 lamps to indicate different stages of grinding there is a pivoted lever which can be observed a pivoted lever with a pad which makes contact with a bore of the component.

This is the pivoted lever other end of the lever is contact with the internal bore of the work piece as the bore is enlarged during grinding the lever turns about the pivot and the other end progressively restricts the outlets causes the air pressure to build up and indicator gives change in the pressure this can be calibrated to show change in the diameter.

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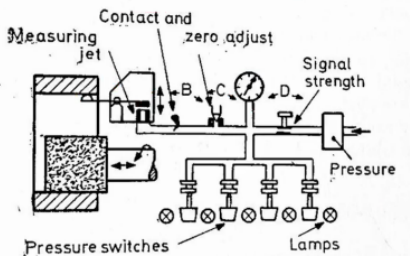
- The increase in pressure causes electrical circuits (relays) to **adjust the feed rate**, the response time being 0.5 sec
- The indicator lights are illuminated progressively for **roughing, semi-finishing, sparking-out with no feed and work-within-limits**
- Finally automatic unloading cycle is initiated



The increase in the pressure causes electrical circuit relays to adjust the feed rate the response time being 0.5 second the indicator lights are illuminated we can see five lamps are there

indicating the stages of progressively for roughing semi finishing sparking out with no feed and work within limits these are the indications given by the lamp finally automatic unloading cycle is initiated.

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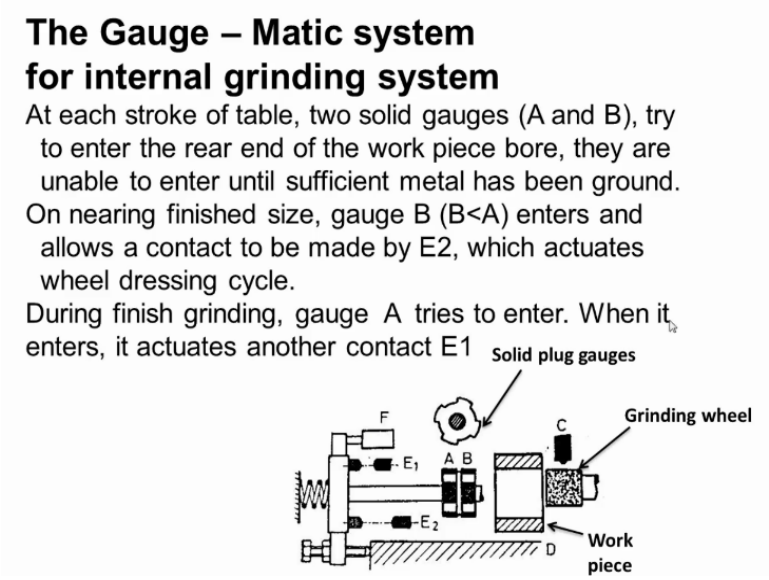

Now there is another system known as gauge matic system for internal grinding operation we can see the arrangement here we can see the spindle of the grinding machine and 2 contacts given and gauging heads which carries 2 solid plug gauges A and B the size of B is smaller than A.

Now this is the work piece and grinding wheel which will grind the internal surface of the work piece now at each stroke of the table 2 solid edges A and B tried to enter the rear end of the work piece bore they are unable to enter until sufficient metal has been ground initially there will be the size of the bore will be smaller because grinding elements these gauges will not enter on nearing finished size.

Gauge b enters and allows the contact to be made by E2 due to the grinding continued grinding the bore size increases at one point of time the gauge B enter in to the bore and the point of time contact made by E2, which actuate wheel dressing cycle and then the diagram pointer comes in to position and this is the wheel finishing can be given during the finish grinding gauge tries to enter.

When the correct size of gauge A enters it actuates another contact E1 this also contacted Now when contact E this will activate the relay grinding wheel is withdrawn machine stops.

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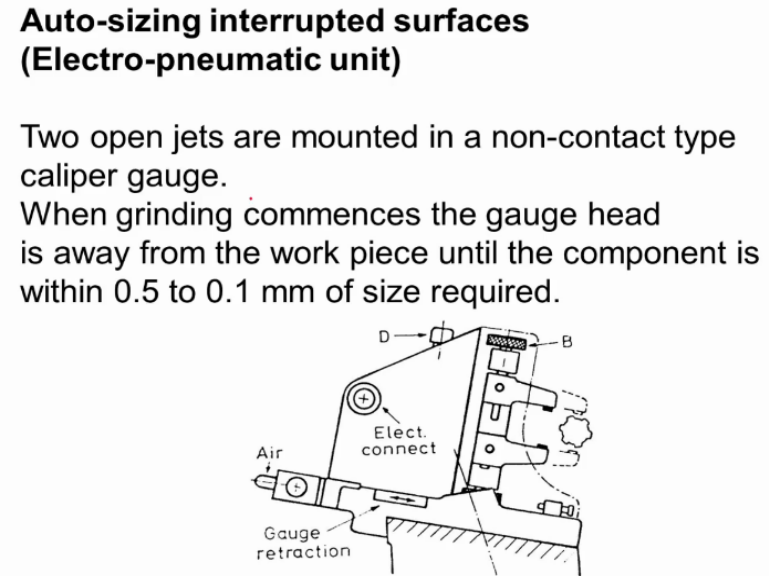

Let us study an auto sizing made for interrupting surfaces and electro pneumatic unit so varying compressed air is used for measurement so here we can see the angle varying we have the jets we have the lighting enlarging these positions there will be a nozzle and compressed air is escaping work piece has spline shaft being ground so in this spline shaft.

We get 2 pressures when there is landing position the gap between the nozzle and the working surface is the pressure is down when this space comes in to position the gap will increase and pressure will be reduced so this electro pneumatic unit is capable of distinguishing between the pressure and increased pressure and reduced pressure In the schematic diagram 2 open jets are mounted in a non-contact type caliper gauge.

When grinding commences the gauge head is away from the work piece until the component is within 0.5 to 0.1 mm of size now see work piece size comes in range of the required size the gauge head is moved to the position.

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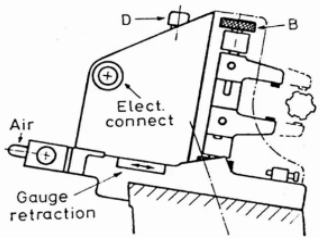
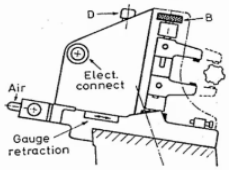
- At this stage an electrical signal is produced, and the gauge head advances the measuring anvils to the pre-set position.
- Grinding continues, when correct size is reached, the gauge head sends a pressure signal to the controller to withdraw the wheel head
- An accuracy of 0.0005 mm is possible



Now at this stage an electrical signal is produced and the gauge head advances the measuring anvils to the pre-set position now we see dashed gauge heads positioned grinding continues when correct size is reached the gauge head sends a pressure signal to the controller to withdraw the wheel head that means when the pressure when the size of work piece there will be certain pressure will equal to pre-set pressure which will withdraw the wheel head an accuracy of 0.0005 mm is possible.

(Refer slide Time: 47:50)

- Knurled wheel B and thimble D are used to adjust the gap between gauge head anvil and spline surface
- The **system differentiates** between large and small **variation in pressure** which occur alternatively as the spaces and lands of surface pass the jets.
- Pressure variation is applied to a sensitive capsule carrying a set of contacts which breaks relay circuit when preset pressures are reached, and wheel head is withdrawn



Now we can observe from the diagram knurled wheel B and thimble D are used to adjust the gap between gauge head anvil and spline surface the system differentiates between large and small variation in pressure which occur alternatively as the spaces and lands of surface pass the jets. Pressure variation is applied to a sensitive capsule carrying a set of contacts which

breaks relay circuit when pre-set pressures are reached and wheel head is withdrawn like this this electro Pneumatic circuit works.

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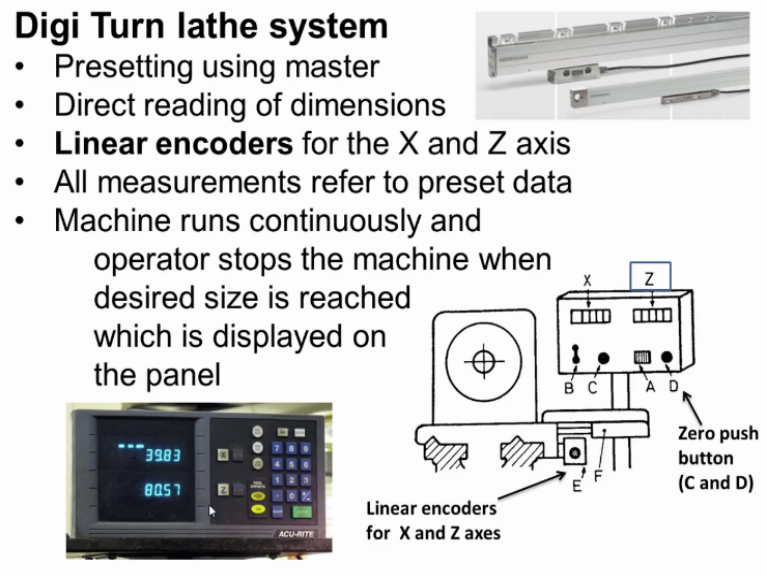

Now let us study a system which is used to gauge turned work pieces called Digi turn lathe system pre-setting using master direct reading of dimensions is obtained linear encoders for X and Z axis we can get direct reading from the display panel using the master work piece we can set the values pre-set values can be input to the system.

We can see 2 buttons are there to setting 0 when master piece is used all measurements refer to pre-set data machine runs continuously and operator stops the machine when desired size is reached which is displayed on the panel will stops the machine.

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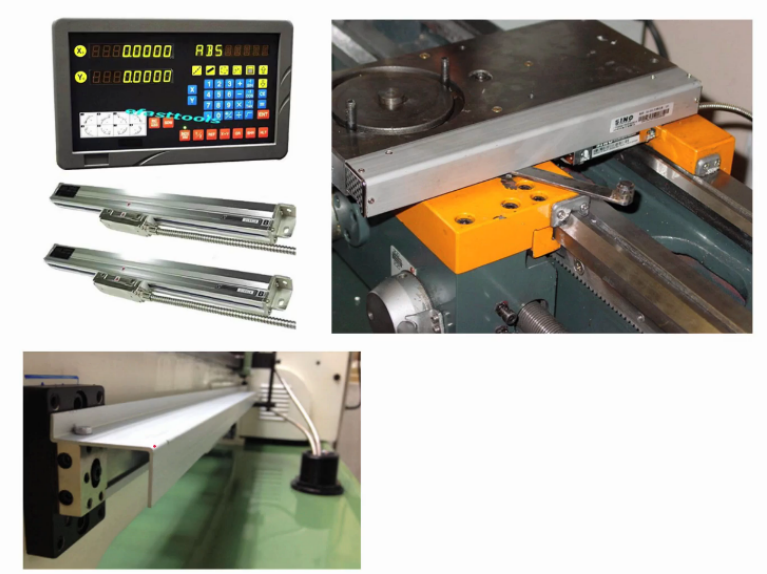

Now here we can see the linear encoders we can see one linear encoder fixed to the head for Z axis, similarly for X axis, there is linear encoder and this is for Z axis and we can observe the appearance of the linear encoders, this is display and this is for X and this is for Z, turning continues the values of the radius and length values are displayed here and operator will be observing, when the correct size is reached, it will stop the machine tool.