ME2400 Project

CNC Surface Grinding Machine

AIM AND OBJECTIVE OF THE PROJECT:

→ To study the working and functionalities of a 3-axis CNC surface grinding machine. We also study the actuator systems used in the machine and the sensors involved in its operation, and to also explain the data acquisition system of this fully automated machine.

→ We also study some of the modifications that can be made to improve the efficiency and ease of use of the CNC surface grinding machine.

WORKING PRINCIPLE DETAILS AND FUNCTIONALITY OF THIS MACHINE:

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Basic Working Principle:

→ It uses a rotating abrasive wheel made of Aluminium Oxide to remove the material from the surface of the workpiece to create a flat surface with high surface finish.

→ The grinding wheel revolves on a spindle motor and the workpiece is mounted on a reciprocating table.

→ The reciprocating table moves in a forward or backward direction and the workpiece is adjusted w.r.t the grinding wheel position.

→ When the power supply is given and a suitable speed is provided to the grinding wheel, the grinding wheel rotates on the surface of the workpiece to remove the material from the surface of the workpiece till high accuracy is achieved.

→ Along the x-axis, which is the bed's axis, a hydraulic drive is used as more load is applied. The hydraulic drive is actuated by a 3 state and 4 port, normally open, solenoid operated directional valve. The alternating movement of oil through the valves creates a reciprocating motion of the bed.

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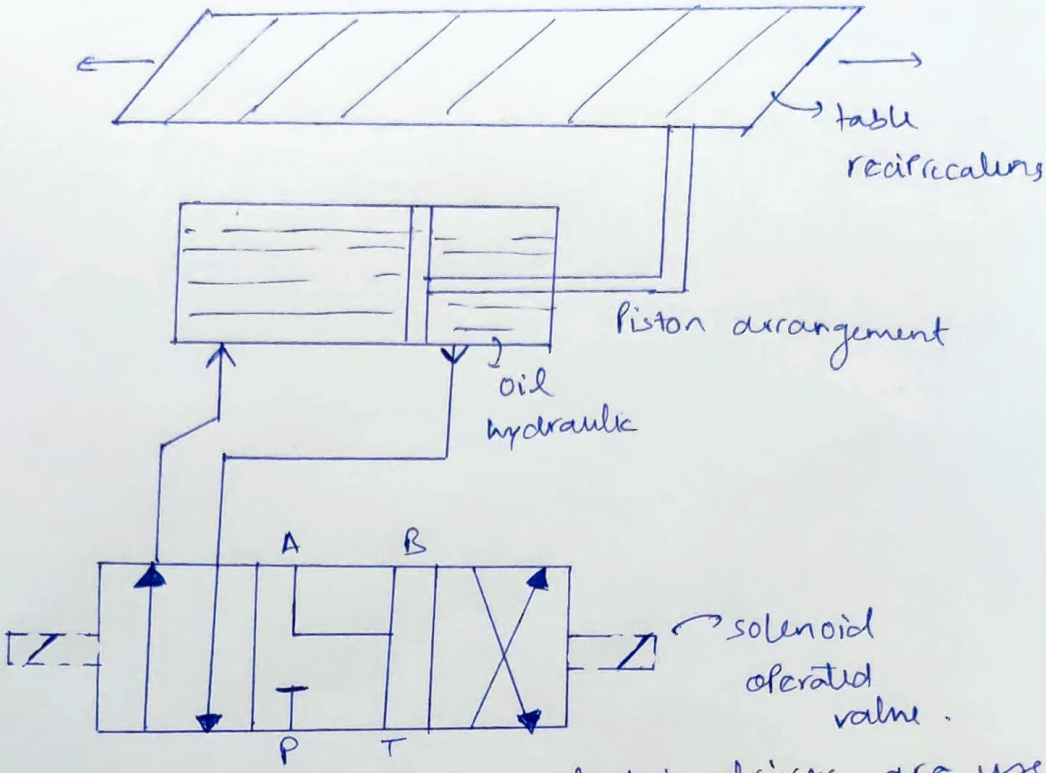

→ Along the y-axis and the z-axis, electric drives are used which are controlled by servo motors as high precision is required and quick movement is necessary.

→ In this way, the CNC surface grinding machine can be used to achieve the set surface finish.

Functionalities of the machine:

1) Accurate depths of cut can be achieved.

2) Different types of grinding can be done by the machine, like criss-cross grinding, Profile grinding.

3) High surface quality finish can be achieved.

4) Fully automated, and if required modifiable operations can be achieved.

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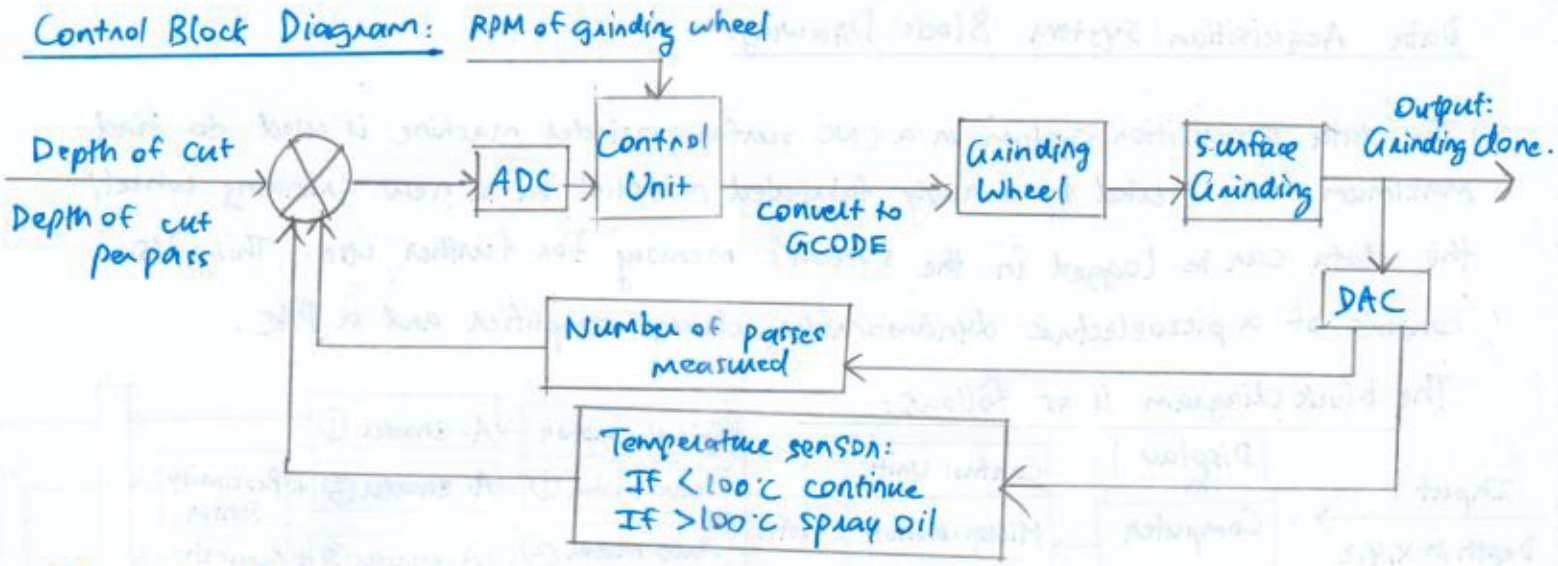
Control Block Diagram:



This is the blocks diagram for the given CNC surface grinding machine.

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CNC Surface Grinding Machine

- **Sensors used & their purpose**

→ Rotary Encoder with magnetic engraving

Used for -

For Measuring Rpm of Spindle

To keep track of rpm of electric servo motors in x, y, z direction

To keep track of rpm of rack and pinion arrangement in x-direction.

Magnetic Rotary Encoders rely on three main components: a disk, sensors and a conditioning circuit. The disk is magnetized with a number of poles around its circumference. Sensors detect the change in magnetic field as the disk rotates and convert this information into a sine-wave and by studying the frequency of the sine-wave the rpm of the rotating object can be calculated.

Specification:

Supply voltage : NA

Pulse : 5000 P/Rev

Resolution : 0.072 Deg

→ Pressure Sensor:

Used for - to pump oil at the required pressure.

For obtaining reciprocating motion of the bed, the oil needs to be pumped in the spool control valve at the required pressure so that it applies sufficient force on the piston.

Specification: NA

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→ Volume flow sensor:

Used to measure the rate at which oil is pumped into piston.

Specification: NA.

→ Limit switch:

Used for safety purposes, ie the bed can't move past the limit switch.

Control Unit / Controller

The user inputs the pattern of grinding he wants using the computer.

The user can input following parameters such as:

- Rpm of spindle motor
- The depth of cut of each pass
- The magnitude of displacement of table
- The movement speed of table.

The computer communicates the above information to the controller. Based upon the input the controller decides the working of the actuators i.e how much voltage/power is to be supplied to the spindle motor as $P = \frac{1}{2} I\omega^2$ (ω = angular velocity), so based on ω requirement power is supplied to the spindle motor. Similarly the Rpm of the electric motor drives that control the y-z direction is controlled in a similar manner ($P = \frac{1}{2} I\omega^2$) by the controller.

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The moment speed of the table in x-direction is determined by the frequency of turning on/off the solenoids (explained in the solenoid actuators) and also depends on the rate of volume pumped.

The two formulas are (refer solenoid control actuator)
Volume pumped = (rate of pumping) * (time for which solenoid is on)
Volume pumped = Area (piston) * displacement

To control the displacement of the table in x-direction the control unit regulates the motor (by changing the power supplied to motor) and frequency of turning on/off the solenoid.

The depth per pass is controlled using the rotary encoder i.e how much the motor should rotate to bring the leadscrew downward by the required amount.
Distance travelled by leadscrew = (No of revolutions) * Pitch.

The control unit has the important task of receiving data through the sensors via the ~~data~~ data acquisition system. Based upon the feedback of the sensors the controller determined what operations should be carried out and the specifics of the operation eg how much longer the motor along the y-axis should run, when the motor should reverse direction etc.

The user inputs the following parameters through the computer. The computer sends the input to controller which based upon the input calls upon the required files from the memory and as the memory files (in hexa-decimal language) is converted to binary language. The binary language is converted to analog

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signals with the help of DAC (R2R DAC for high resolution) and passed on to actuators - spindle motors / Ac servo motors or solenoid valves and the required set of output is obtained.

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SIGNAL CONDITIONING DETAILS

In the process of signal conditioning there isn't much noise picked up from the sensors hence amplification alone is sufficient. one of the cases is the measurement of RPM of the spindle by the rotary encoder, the signal from the rotary encoder is conditioned (amplified using an opamp circuit) and sent to the microcontroller where the speed is calculated.

A/D and D/A converters

the electric drive is controlled by a servo motor, here the input value of distance is converted to a PWM signal and sent to the servo motor.

the grinding wheel RPM can be set by giving both analog and digital inputs, in case of digital input a D/A converter converts the value to analog input to motor and it rotates in the specified RPM

ACTUATORS

Solenoid control valve

the x-coordinate of the bed is determined by the position of the piston. the piston can be moved either way by pumping in water in position 1 or 2.

If water is pumped in position 1 the piston moves leftward and if water is pumped in position 2 piston moves rightward.

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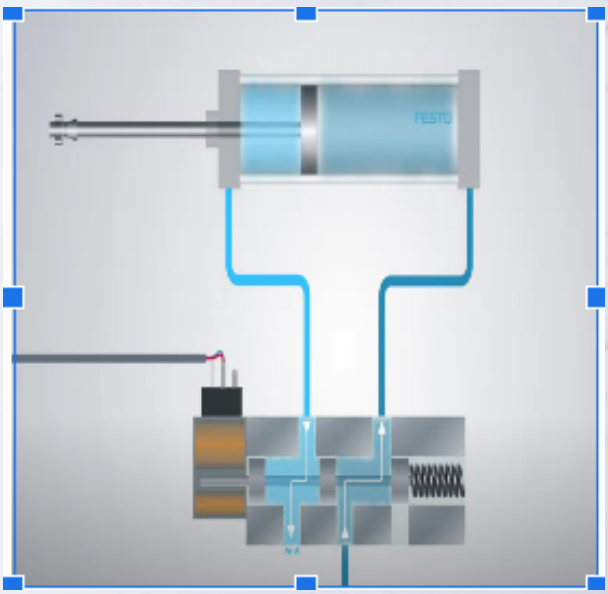
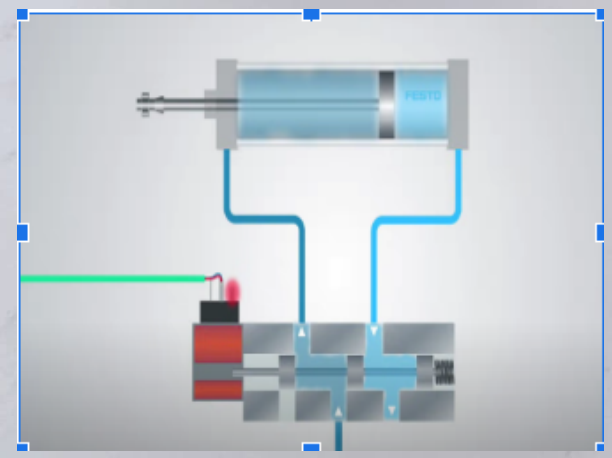
By carefully adjusting how much water is pumped in, the extent/magnitude of displacement of the piston can be controlled

The Volume pumped = Area * displacement
(area of piston)

Volume pumped is directly proportional to the rate of water pumped by motor and time period for which solenoid is in position 1 or 2.

Volume pumped = (rate of pumping) * (time for which solenoid switch is ON





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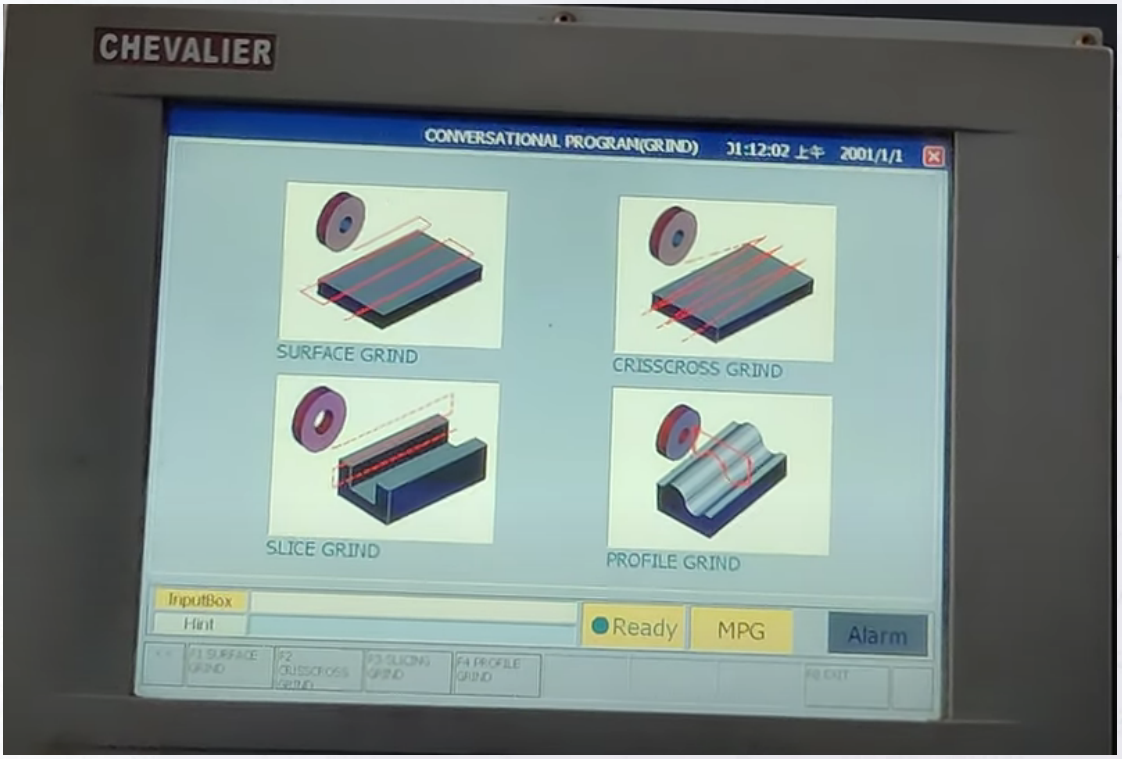
there is a FRL (Filtering Regulating and Lubricating) unit which cools the spindle, this FRL unit is controlled by a pneumatic system which sprays high pressurized air with coolant fluid.

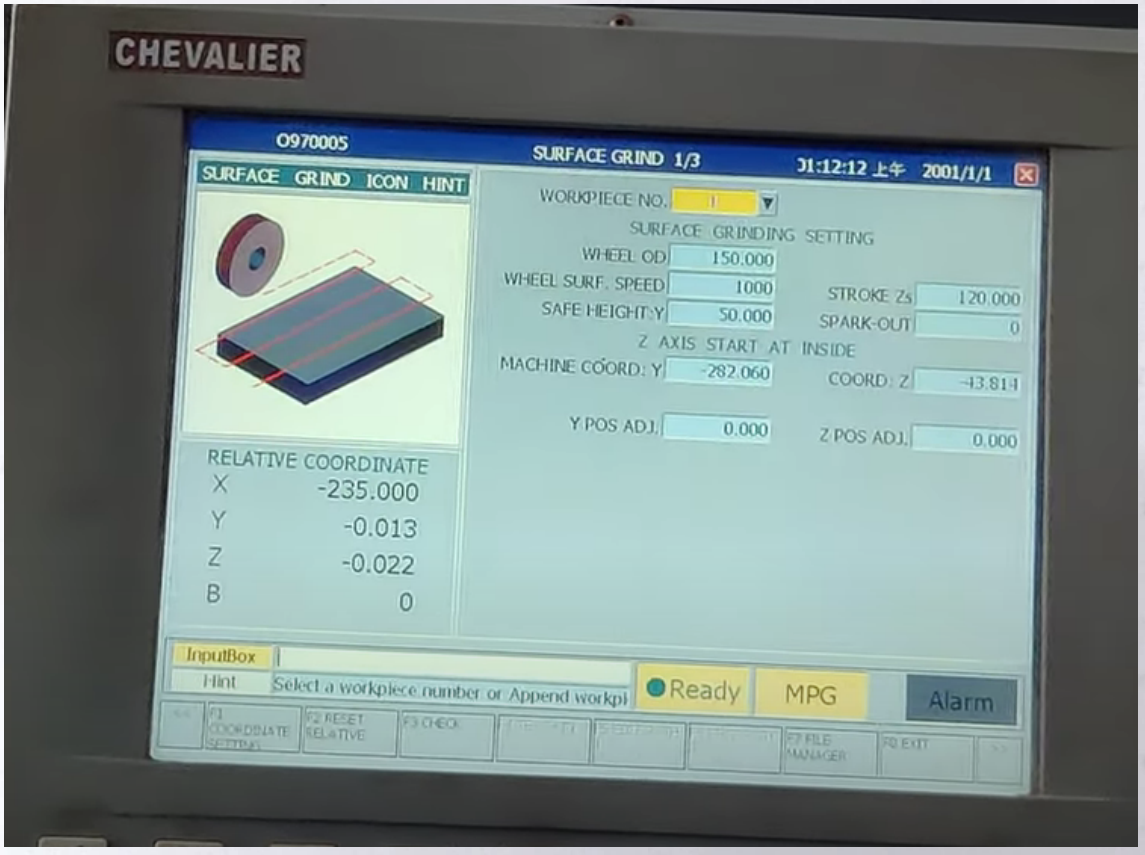
Magnetic chuck is an electromagnetic setup on the machine bed which when turned ON holds metallic workpieces in place so that the workpiece doesn't drift during operation due to the force experienced by it from the grinding wheel. This electromagnetic setup can be turned ON/OFF by the user.

DISPLAY

There is a LCD display for interfacing, there are 4 basic options for grinding i.e criss-cross grinding, plane grinding profile grinding, surface grinding.
For example if surface grinding is selected then the wheel specifications are to be entered and then stroke length in X, Y, Z directions, then the origin needs to be set spark out has to be specified as well.
Then we need to specify the cut parameters like depth of cut, number of passes, and rough grind and fine grind specifications as well. After feeding these inputs the CNC machine converts all this into G-code and inputs this into the control unit

which executes the operation.





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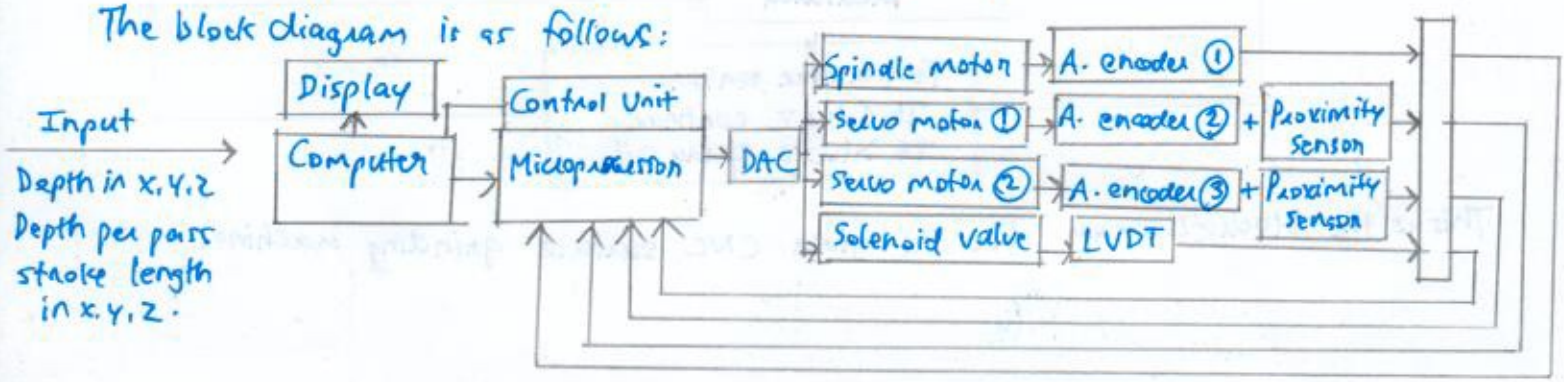
Data Acquisition System Block Drawing:

→ The data acquisition system in a CNC surface grinder machine is used to find maximum force exerted by a newly fabricated material on a new grinding wheel; this data can be logged in the system's memory for further use. This DAS consists of a piezoelectric dynamometer, charge amplifier and a DAC.

The block diagram is as follows:



LVDT - To record spool position.

→ The piezoelectric dynamometer gives an analog value of the force in terms of charge. The charge amplifier amplifies the charge given by the dynamometer and then the signal is sent to DAC (Data Acquisition Control) for converting it to digital signal. It is then stored in system memory.

When we use this particular grinding wheel for further operations we can enter it in the system and get required data such as the maximum depth of cut that can be achieved using the wheel per pass.

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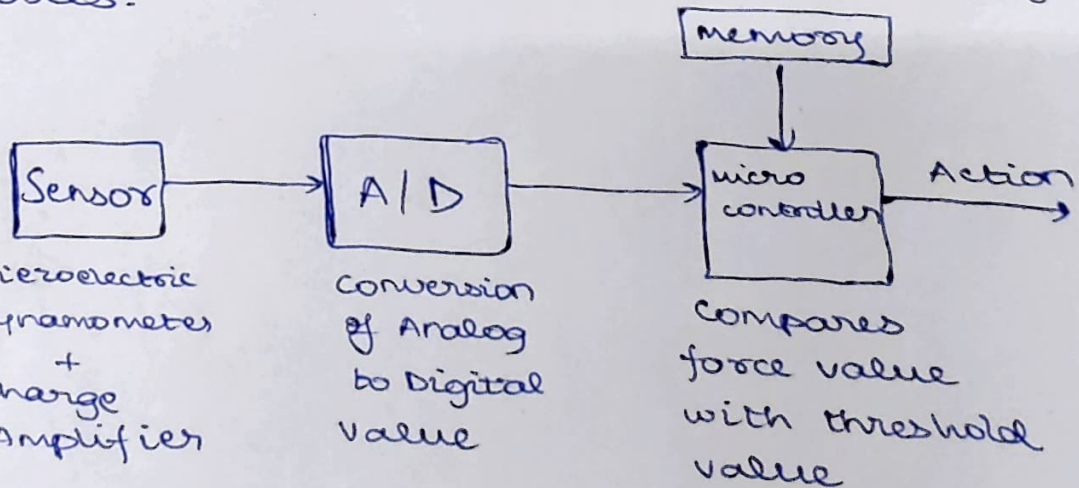
APPROACH TO MODIFY/ALTER WITH JUSTIFICATION

An area where the machine's efficiency can be increased is for automatic dressing, we can have a mechanism that can detect when a grinding wheel is loaded beyond its threshold value and then it can automatically dress the grinding. This can be achieved by using a Data Acquisition System that can measure the force from the grinding wheel at end of each operation and it can compare this value with the set threshold value which varies for each grinding wheel. So if at the end of our operation the load is greater than threshold value then the wheel will be automatically dressed in an area adjacent to the machine bed called the dressing bed. This will reduce human errors as till now dressing will be decided by operator who can make human errors but now the grinding wheel can be dressed at the right load. This also saves cost in dressing the wheel and saves power as loaded wheels have blunt edges which require greater forces.



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