Control of the Grinding Process Using In-Process Gage Feedback

PMRC Industrial Advisory Board Meeting

Georgia Institute of Technology

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Overview

- ❖ Research Objective
- ❖ Need for Research
- ❖ Internal Grinding Model Development
- ❖ External Grinding Model Development
- ❖ Experimental Methodology
- ❖ Importance of Research
- ❖ Summary

Research Objective

- To regulate the part diameter size variation and cycle time of a high volume dedicated grinding machine process using a externally applied control strategy to adjust the feedrate of the machine.

Need for Research

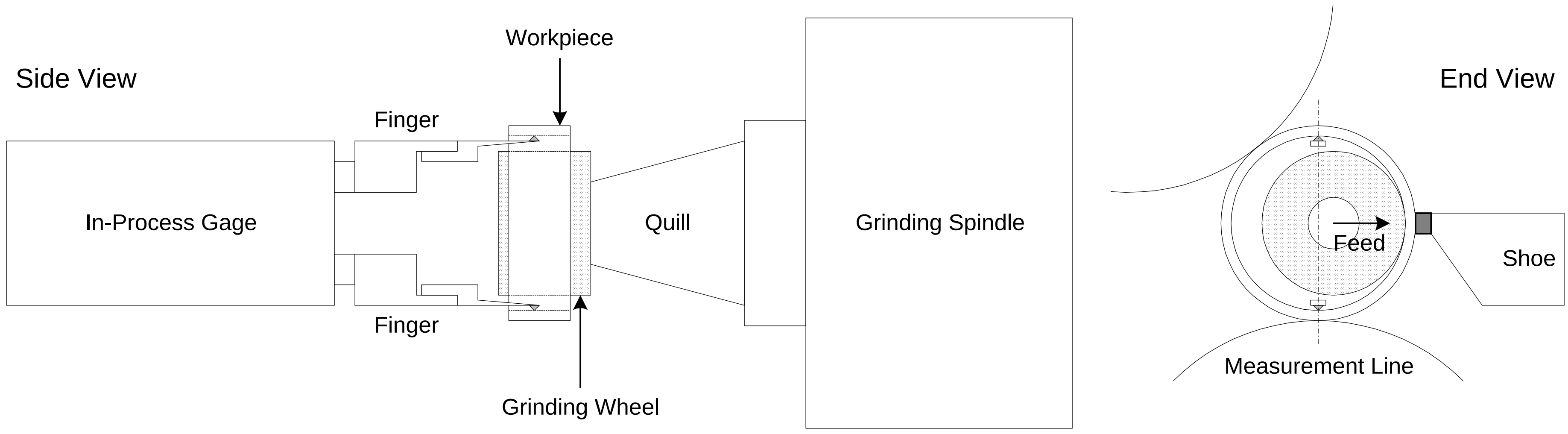
- To realize the potential of gage systems resulting from advances in machine tool design and control
- To overcome limitations of traditional control strategies by using in-process diameter gage feedback

In-Process ID Gage Detail

- Two diamond-tipped tactile probes
- Provides direct measurement of diameter
- Feed perpendicular to measurement line

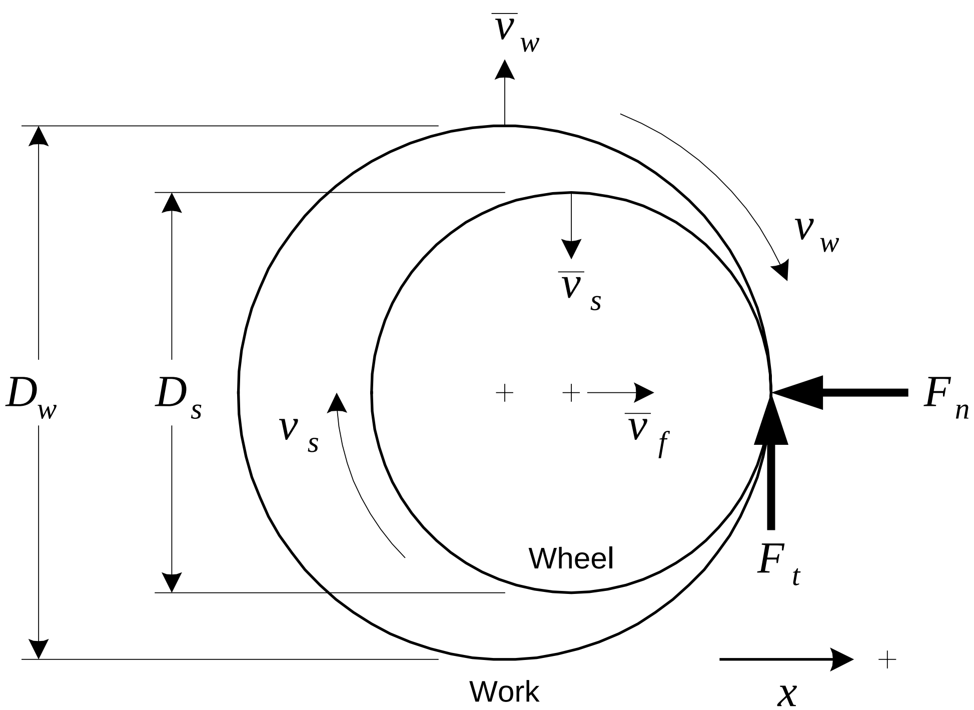
Typical Grind Cycle

load part
wheel in
gage in
grind
retract spindle
retract gage
load part
...



Internal Grinding Schematic

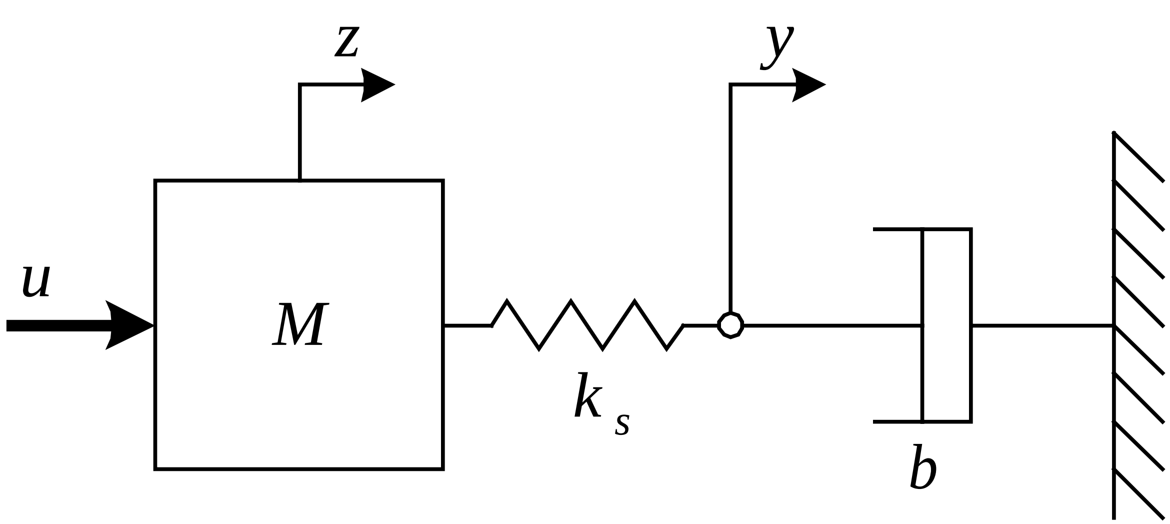
Deflection $\Delta x = \left(\bar{v}_f - \bar{v}_w - \bar{v}_s \right) \Delta t$



D_w	Work piece diameter
D_s	Grinding wheel diameter
$\bar{v}_w$	Work piece diameter rate of change
v_w	Work piece surface velocity
$\bar{v}_s$	Grinding wheel diameter rate of change
v_s	Grinding wheel surface velocity
$\bar{v}_f$	Grinding wheel velocity
F_n	Normal force
F_t	Tangential force
W	Grinding contact width (not shown)

Internal Grinding Dynamic Model

- Grinding system elements
  - System mass, M
  - System stiffness, k
  - Servo system input, u
  - Grinding process dynamics, b
  - Slide position, z
  - Grinding wheel position, y
  - System deflection, (z - y)

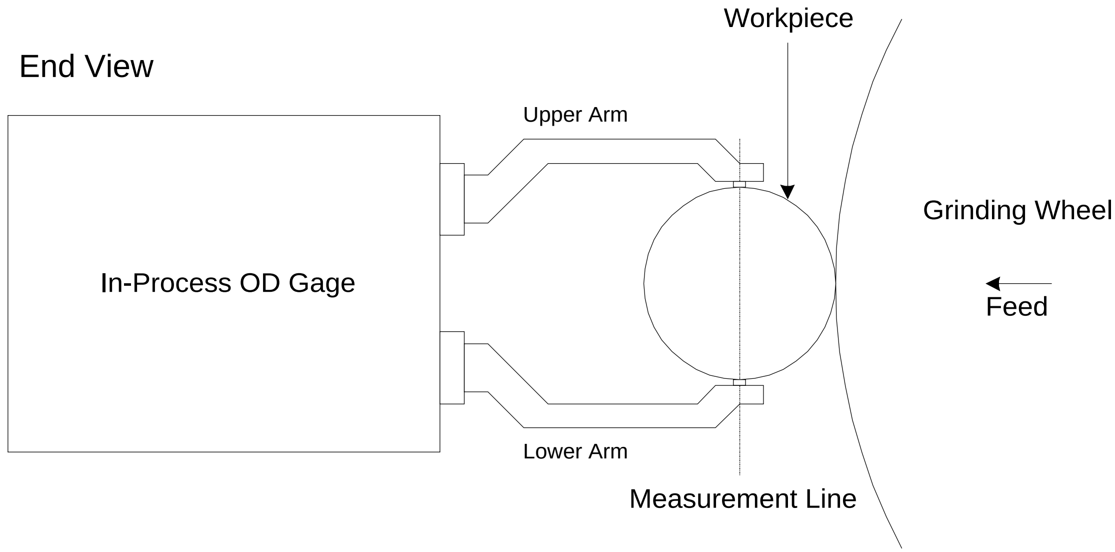


In-Process OD Gage Detail

- Two diamond-tipped tactile probes
- Provides direct measurement of diameter
- Feed perpendicular to measurement line

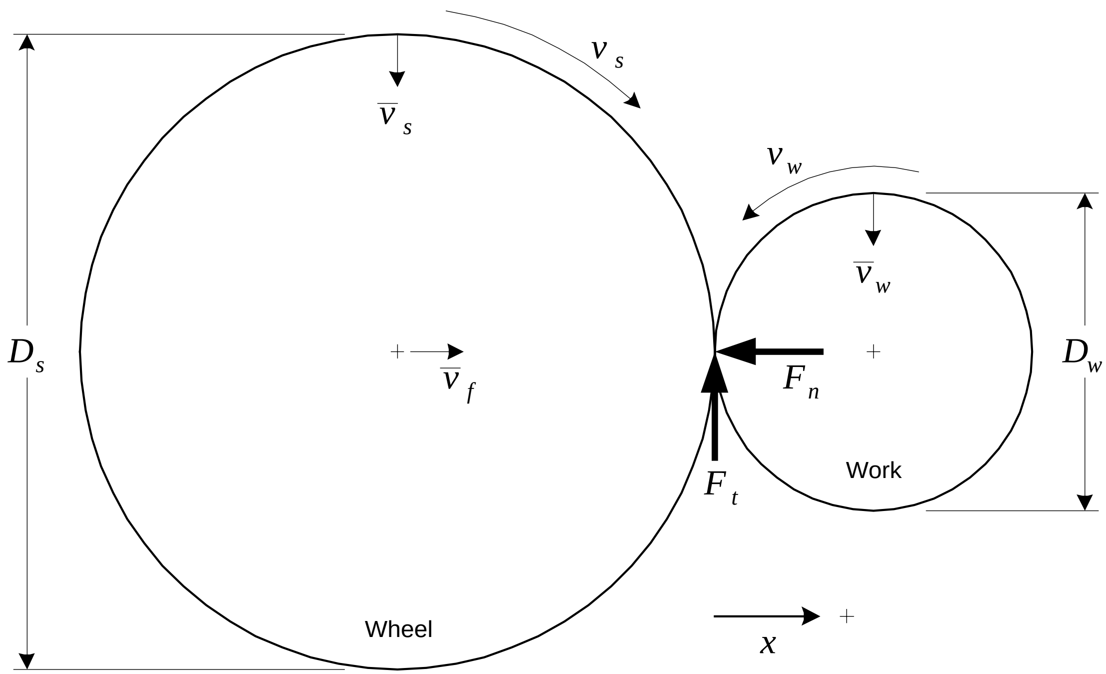
Typical Grind Cycle

load part
wheel in
gage in
grind
retract spindle
retract gage
load part
...



External Grinding Schematic

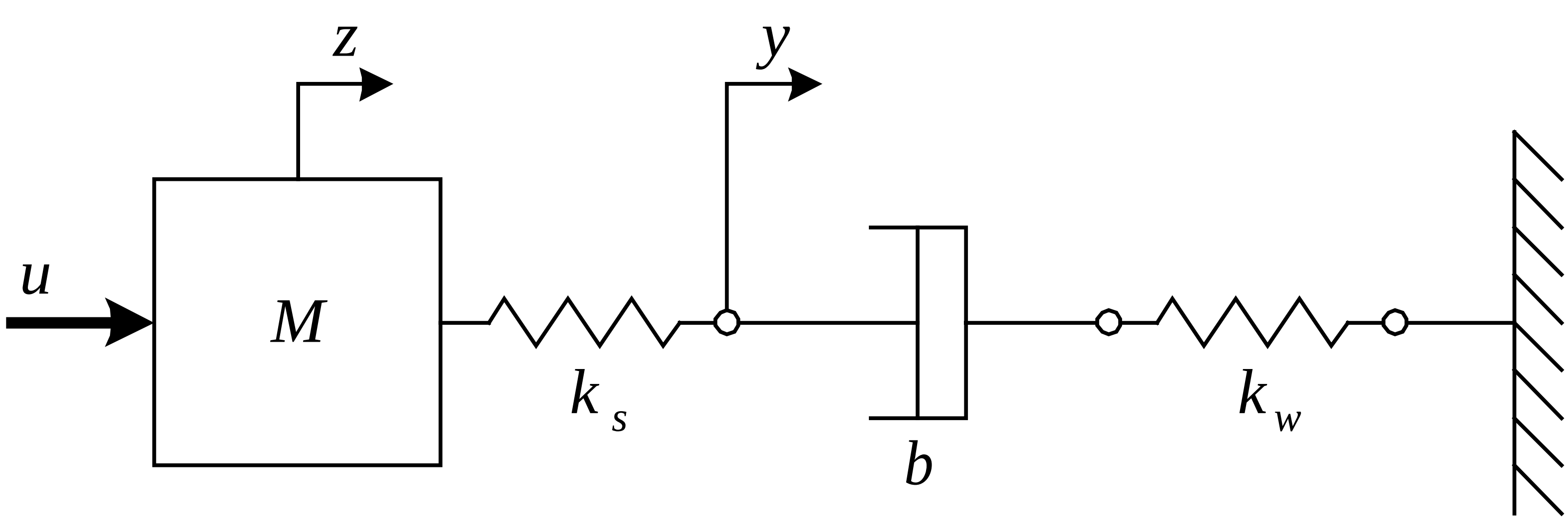
Deflection $$\Delta x = \left(\bar{v}_f - \bar{v}_w - \bar{v}_s \right) \Delta t$$



D_w	Work piece diameter
D_s	Grinding wheel diameter
$\bar{v}_w$	Work piece diameter rate of change
v_w	Work piece surface velocity
$\bar{v}_s$	Grinding wheel diameter rate of change
v_s	Grinding wheel surface velocity
$\bar{v}_f$	Grinding wheel velocity
F_n	Normal force
F_t	Tangential force
W	Grinding contact width (not shown)

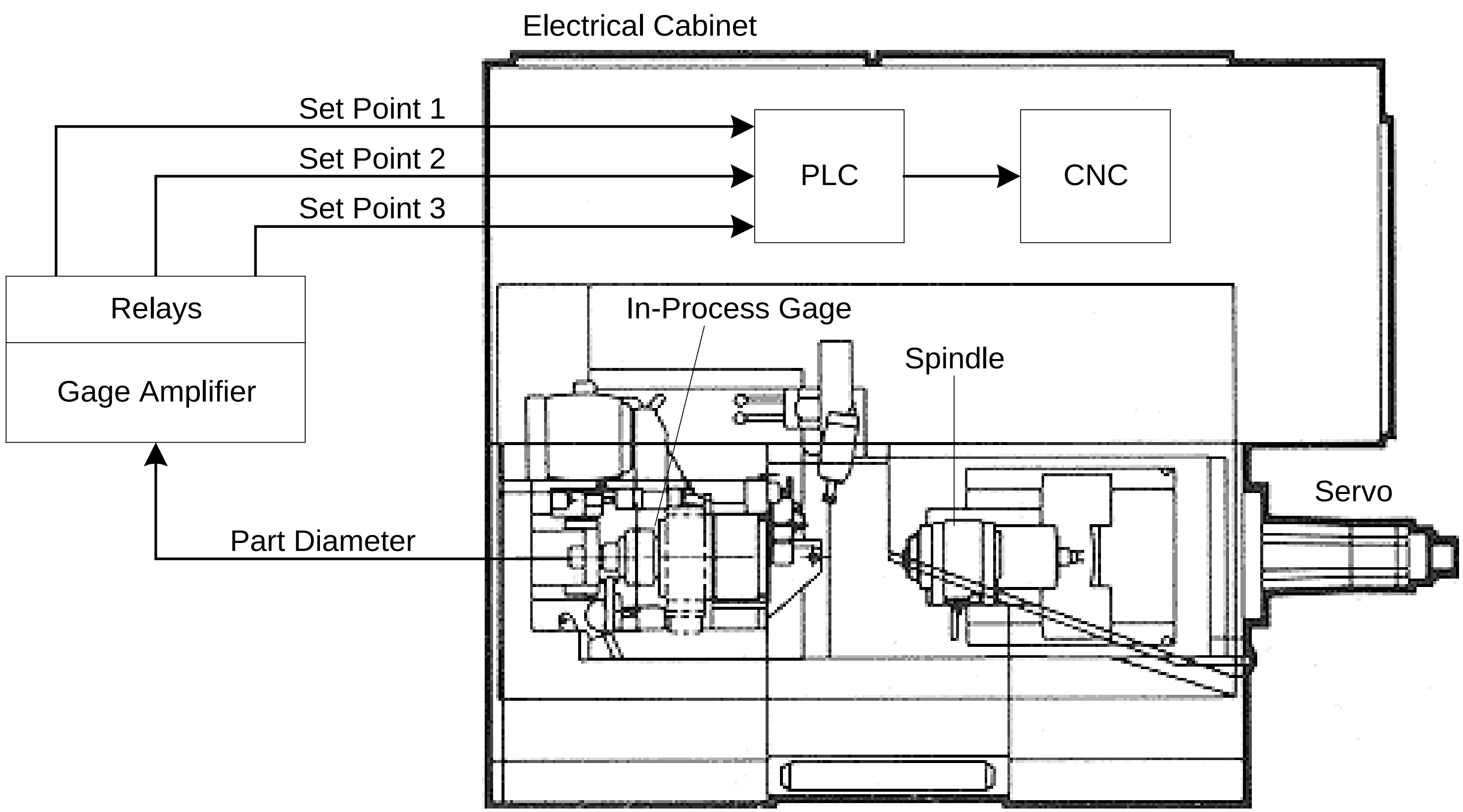
External Grinding Dynamic Model

- Grinding system elements
  - System mass, M
  - System stiffness, k
  - Servo system input, u
  - Grinding process dynamics, b
  - Slide position, z
  - Grinding wheel position, y
  - System deflection, $(z - y)$

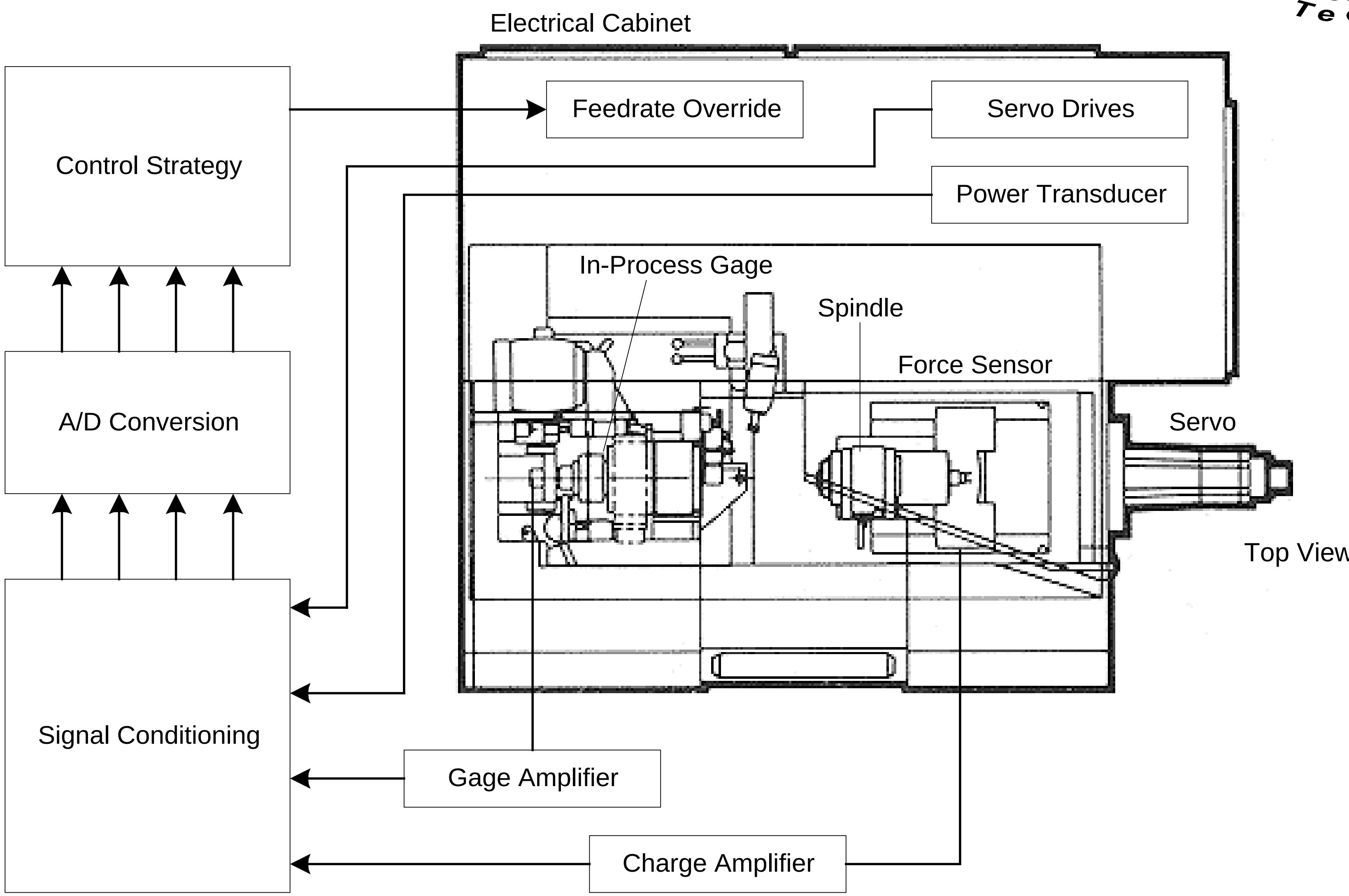


Traditional Gage Sizing Setup

- Cycle time limitations using fixed set point control
- Relay and PLC delay increases part diameter variation



Experimental Setup



Importance of Research

- First use of continuous part diameter feedback to control the grinding process
- Will be a standard feature on all future dedicated high volume production grinding machines
- Will reduce costs and make high volume components less expensive to produce
- Will be able to control any machine with gage diameter feedback to reduce cycle time and part diameter size variation

Summary

- Part diameter information from an in-process gage as feedback to the control of a non-trivial machine tool process
- Internal and external grinding process dynamic model development
- Implementation and evaluation of control design on an external universal grinder at Georgia Tech