Update of Process Monitoring and Control Research at NC State University

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Update of Process Monitoring and Control Research at NC State University

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OBJECTIVE
(Process Monitoring)

• Alert operator when an undesirable condition arises.

Monitoring Parameters: power consumption, spindle vibration, spindle temperature, etc.
OBJECTIVE
(Process Control)

- Maintain optimum feed speed and product quality regardless of changes in workpiece properties and tool condition.

Control Parameters: spindle vibration, cutting forces, acoustic emission, cutting sound, etc.
PROCESS MONITORING

Processes Monitored
- Router
- Wide Belt Sander
- Moulder
- Tool Grinder

Objective:
Use process data collected from sensors/transducers to evaluate machine performance

Parameters Monitored
- power
- cutting forces
- vibration
- workpiece temperature
- acoustic emission
- spindle temperature
- workpiece surface quality
PROCESS MONITORING
- Power

- Width of Cut
- Workpiece S.G.
- Tool Diameter
- Moisture Content
- Tool Dullness
- Depth of Cut
- Spindle rpm
- No. of Knives
- Feed Speed
- Rake Angle
PROCESS CONTROL - Router

- Length of Cut (meters)
  - 0 100 200 300 400 500

- Tool Wear (nose width - µm)
  - 0 10 20 30 40 50 60

- Computer Controlled Spindle Speed
- Constant Spindle Speed (18,000 rpm)

- Number of Cutting Passes
  - 0 50 100 150 200

- Area Under Power Spectrum of Acceleration (V²)
  - 0 10 20 30 40 50 60

- 10 Hz - 1000 Hz Filter
- 1000 Hz - 4000 Hz Filter

- Tool Wear (nose width - µm) vs. Length of Cut (meters)

- Computer Controlled Spindle Speed
- Constant Spindle Speed (18,000 rpm)
CURRENT WORK

Determine best sensor or combinations of sensors for various abrasive operations

Sensors evaluated: power, vibration, microphone, acoustic emission, machine vision system, optical color contrast detector, and surface quality assessment
Peripheral Sanding

Objective:
Use Sound, AE, Vibration, Optical, and Surface Quality Sensors, to Detect Abrasive Loading and Wear
Acoustic Emission Monitoring for Peripheral Sanding

AE is sensitive to material removal rate, species, grit, WEAR but not loading
Objective:
Use Sound, AE, Vibration, Optical, and Surface Quality Sensors, to Detect Abrasive Loading and Wear
Color Contrast Detector

[Graph showing the relationship between Machining Time (minutes) and Color Contrast]
Camera: Grey Scale Intensity

Grey Scale Intensity

Machining Time (minutes)

0 10 20 30 40 50 60 70
Theory of Operation of Optical Profilometer

Surface Quality Assessment

RESULTING SURFACE PROFILE

Y1

X1

Y2

X2

DETECTOR

LASER BEAM

MAGNIFIED WOOD SURFACE

SAMPLE PROFILE PLANE

FEED DIRECTION

WOOD SURFACE

FEED DIRECTION
Surface Quality Assessment

100 Grit on Oak

Vibration on Wide-Belt Sander
EXAMPLE OF DETECTING MACHINING DEFECTS

ISO G1 Tool Unbalance

ISO G16 Tool Unbalance
MONITORING A MOULDING OPERATION

Unjointed Knives

Jointed Knives

Frequency Spectrum of Surface Height (µm)

Frequency (Knife Marks Per 25 mm)
Surface Quality Assessment

Sanding ridge on particleboard
Surface Quality Assessment

Sanding ridge on maple
MONITORING TOOL WEAR ON A MOULDER (MDF)

Sharp Tool

After 70,000 linear feet

After 150,000 linear feet

Displacement (µm) vs. Scan Length (mm)
FUTURE WORK

• Setup Proper Lighting for Machine Vision

• Conduct Vibration Studies on other routers and sanders

• Evaluate Effect of Machine Parameters and Abrasive Cleaning

• Develop Control Strategies
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