A Review of Extruder Automation Systems

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AUTOMATION in ALUMINIUM EXTRUDERS

Total plant automation

Process Control and optimisation

Quality control Diagnosis

Process evaluation

Production planning and management

Data
- acquisition
- communication
- archiving
- management

Visualisation

Feedback control

Measurement
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2. AUTOMATION TASKS to be PERFORMED in EXTRUSION . . .

**Goal**

Raise quality, increase productivity, increase robustness of production

**Tasks involved**

*Process Control* of motion, temperature, force etc.
*Archiving* and data evaluation
*Monitoring and visualisation* of process variables
*Alarms* and interlocks

**Means available for Process Control**

Sensors (incl. pyrometers!)
Methods and algorithms for control
Hardware and methods for signal processing and communication
2. AUTOMATION TASKS to be PERFORMED in EXTRUSION

**Billet Handling**
- Billet transport
- Billet loading
- Billet heating \( \text{Control} \)

**Extrusion**
- Ram movement \( \text{Control} \)
- Profile temperature \( \text{Control} \)

**Profile Handling**
- Assess profile properties \( \text{Image processing} \)
- Cool profile
- Puller movement \( \text{Control} \)
Goal: Increase productivity, enhance product quality

For productivity:
Maximise extrusion rate

For product quality:
Extrude under prescribed conditions e.g. extrusion temperature and rate

To achieve both simultaneously:
Employ tight control of extrusion rate and temperature

Iso-thermal - Iso-rate Extrusion
2. AUTOMATION TASKS to be PERFORMED in EXTRUSION . .

Process Control for optimal production:

*Prescribe* values of relevant process variables appropriately

*Extrude* such that the variables take on the prescribed values

Process variables which influence product quality:

- Billet temperature,
- Extrusion force, ram speed, profile speed
- Profile exit temperature,
- Cooling of profile
2. AUTOMATION TASKS to be PERFORMED in EXTRUSION

For prescribing values appropriately
- Use experience and knowledge (Capital of Plant !!!)
- Gather data, analyse it and store optimal values in a data-bank and retrieve when required

To extrude such that values of the variables are held in prescribed ranges
- Display process variables and let the operator control inputs manually
  - Use automatic control
  - Use a combination of both
2. AUTOMATION TASKS to be PERFORMED in EXTRUSION

Billet temperature: Contact or non-contact temperature measurement

Profile temperature: Non-contact temperature measurement

For non-contact measurement: Radiation pyrometers
- Available since ca. 1990
- Continuously improved

Issues
- Alignment
- Calibration
- Robustness
2. AUTOMATION TASKS to be PERFORMED in EXTRUSION

Strategy for Extrusion Control

Objectives:  
- Isothermal extrusion control  
- Isothermal iso-rate extrusion control  
- Robustness of control

Control inputs:  
- Extrusion velocity  
- Billet temperature / - taper  
- Valve position of hydraulics  
- Velocity of billet/quench ring

Hitherto:  
- Feedforward control (simulated extrusion)  
- Feedback control (on-line)

Better:  
- Employ control from cycle to cycle

 Iterative Learning Control (ILR)
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3. An AUTOMATION SYSTEM for ALUMINIUM EXTRUDERS...

MoMAS - Modular Measurement and Automation System

- Extruder press
- Billet heating
- PC with MoMAS-Software
- Pyrometers
- Billet
- Ram
- Force sensor
- Position sensor
- Cooling
- Link
- PLC
- Pyrometer
- Billet heating
- Furnace
3. An AUTOMATION SYSTEM for ALUMINIUM EXTRUDERS

Learning algorithm

\[ u_{k+1}(l) = u_k(l) + \Delta u_{k+1}(l) \quad \text{(Optimal ram speed / billet temp.)} \]

\[ \Delta u_{k+1}(l) = F[\vartheta_d(l), \vartheta_k(l), \vartheta_{k+1}(l), \vartheta_{B_k}(l), \vartheta_{B_{k+1}}(l), p_{k+1}(l), v_k(l), v_{k+1}(l), \Delta \vartheta_{k+1}] \]

with:
- \( \vartheta_d(l) \): Desired run of exit temperature
- \( u_k(l) \): Input as a function of extruded length of cycle \( k \)
- \( v_k(l) \): Ram velocity in current cycle \( k \)
- \( \vartheta_k(l) \): Run of exit temperature in previous cycle \( k \)
- \( \Delta \vartheta_{k+1}(l) \): Increment of input calculated for cycle \( k+1 \)
- \( \vartheta_{B_k}(l) \): Billet temperature in cycle \( k \)
- \( p_{k+1}(l) \): Extrusion force in current cycle

\( F[...\] \) to be chosen (based on model) for fast convergence.

With exact model convergence to optimal input in 1 cycle!
3. An AUTOMATION SYSTEM for ALUMINIUM EXTRUDERS

MoMAS® Display at operator console
3. An AUTOMATION SYSTEM for ALUMINIUM EXTRUDERS
3. An AUTOMATION SYSTEM for ALUMINIUM EXTRUDERS

The functions to be performed:

- measure and display process variables profile exit temperature, extrusion force, ram velocity etc. during every cycle and extrusion time per billet, idle times and the mean temperature over the cycles
- calculate the optimal process input functions and transfer this to the PLC
- determine best process inputs for an order, store them and retrieve them automatically when needed
- provide the extruder managers and engineers with a data base for monitoring and evaluation
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4. INSTALLED SYSTEMS

First industrial installation: SAPA, February 2001

Presses in which MoMAS® has been installed

- 6 presses in Germany (SAPA, ALCAN, AWB, HMT and FZS)
- 1 press in Sweden (SAPA)
- 2 presses in Italy (ALEX and COMETAL)
- 2 presses in USA (SAPA)
- 4 presses in Australia (CAPRAL)
- 4 presses in Russia (Minsk)
- 1 press in Korea (Kores)
4. INSTALLED SYSTEMS

Installation steps

Install hardware

- sensors in particular Pyrometer(s), (Plant crew)
- PC (Plant crew)

Install / modify software

- In PLC . . install OPC (Plant crew / System integrator)
- modify PLC programme (Plant crew / System integrator)

- In PC . . install MoMAS® (MoMAS Team)

Connect PLC with PC, activate communication link and MoMAS®
(Plant crew / System integrator , MoMAS Team)
4. INSTALLED SYSTEMS . .

Execution


MoMAS Team + Firm COMETAL : 10 installations (2003 - 2005)

MoMAS Team + BEC : 4 installations (2007 - 2010)

MoMAS Team + RUN Automation : current installations

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Production Statistics of Extruder equipped with MoMAS® at SAPA Offenburg

<table>
<thead>
<tr>
<th></th>
<th>No. of billets extruded</th>
<th>Mean extrusion rate</th>
<th>RMS error of exit temp. °C</th>
<th>Standard deviation of °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>With MoMAS</td>
<td>30 381</td>
<td>10.02 mm/s</td>
<td>12.1°C</td>
<td>3.89°C</td>
</tr>
<tr>
<td>Without MoMAS</td>
<td>26 180</td>
<td>9.29 mm/s</td>
<td>(28.8°C)</td>
<td>4.21°C</td>
</tr>
</tbody>
</table>

Actual production statistics for the period May - September 2001 of an extruder in Offenburg

Note increased mean extrusion rate of > 6%
5. EXPERIENCE with INSTALLED SYSTEMS

Feedback from plants

Weight of conditions which prevent more use

<table>
<thead>
<tr>
<th>Condition</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature measurement with pyrometer is not reliable</td>
<td>2</td>
</tr>
<tr>
<td>Billet temperature stability</td>
<td>2</td>
</tr>
<tr>
<td>Operators are not motivated</td>
<td>2</td>
</tr>
<tr>
<td>Speed control is not adequate</td>
<td>4</td>
</tr>
<tr>
<td>Batches are too small, frequent die change</td>
<td>4</td>
</tr>
<tr>
<td>Frequent interruptions of communication between PC and PLC</td>
<td>1</td>
</tr>
<tr>
<td>Other (pl. specify)</td>
<td></td>
</tr>
</tbody>
</table>

Scale for Weight: 1 (least) to 5 (highest)
5. EXPERIENCE with INSTALLED SYSTEMS

a) Critical issues: System related issues

- **Profile temperature measurement with pyrometer**
  Installation alignment after every die change
  Lateral wandering of the profile

- **Billet temperature measurement and control**
  Billet temperature control is often a problem.
  The billet furnace has an inherent lag over the cycles.
  Measure temperature along axis of billet as it is introduced into the recipient.
  Measures have to be implemented to clean the pyrometer lens.

- **Ram velocity control**
  Velocity control tracking with small error
  Limitations of the extrusion force cause unsatisfactory velocity control behaviour.
5. EXPERIENCE with INSTALLED SYSTEMS

b) Critical issues: Operator related issues

- Operator motivation is crucial.
- Additional burden on operator to be avoided - Use PLC operator inputs and default values for automation system.
- Check pyrometer alignment after every die change. The operator sees this as a burden. The attitude changes, if he sees automation is a help.

Strategy: Identify and concentrate on one smart operator with potential and make him spread the word!
5. EXPERIENCE with INSTALLED SYSTEMS

c) Critical issues: Management related issues

- Commercial viability is not fulfilled: extruders not working at full capacity, cost saving due to reduced production time is neglected.
- Earlier unsuccessful attempts give rise to doubt: operators are sceptical and managers uncertain whether the new offered system is any better.
- A scenario: It is seen that current conditions could be modified for exploiting the automation system fully (e.g. a better ram speed control system or a more powerful PLC).
  Project is then shelved!
- More pressing issues

- Personal and emotional factors
5. EXPERIENCE with INSTALLED SYSTEMS

Desired features ...

- **From operator crew viewpoint:**
  Ease of use without special training
  Actions only at the PLC console
  Few or no additional knobs
  Simple and transparent control principle

- **From maintenance crew viewpoint:**
  Open and autonomous PLC- software
  Simple set-up and configuration / commissioning
  Debug function
  Self help by changes in PLC or data base system.
Desired features

- *From IT crew viewpoint:*
  Simple data base connectivity via different protocols

- *From management crew viewpoint:*
  Return of Investment - *productivity, product quality*
  Enhanced robustness of production process
  No additional person(s) to be employed for maintenance
  Integration of automation system into overall IT and production
Extruder plant Types

a. *Plants belonging to corporate concerns*
   Knowledge and expertise in the extrusion process and capacity for introducing new technologies is available.

b. *Plants which are one-off or a few-off, owned by single owners*
   Production of high end products
   Knowledge and expertise in extrusion process and capacity for introducing new technologies is available.

c. *Plants which are like b. in structure*
   Production of bulk products (in a limited product range)
   Knowledge and expertise in extrusion process and capacity for introducing new technologies is available only to a limited extent. This is compensated by the enthusiasm to try out new methods for achieving increased tonnage. Decision process can be quick.

*Surprisingly, plants of Type c. profit considerably by installing an automation (Robust Production !).*
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6. **CONCLUSIONS**

Factors to be considered for deciding to go in for automation

*Commercial viability*
- Is extruder plant working at its full capacity?
- Is there a demand for increased product output?
- Is a new market sector being envisaged?

*Technical feasibility*
- Are the hydraulics and ram position / speed control adequate?
- Is the billet furnace temperature control in order?
- Is the puller control adequate?
- Is the PLC capable of handling the data traffic?

*Acceptance by the crew*
- Are all involved people committed?
- Is the crew capable of coping with the new system?
6. CONCLUSIONS

Conclusions

- Contactless temperature measurement of extruded aluminium with high accuracy is feasible
- Advanced extruder control based on exit temperature monitoring offers an useful tool for total automation
- Automation can yield increased tonnage and improved product quality increased robustness of production process

Condition of the plant and commitment of the people are crucial for the successful application of automation
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Thanks for looking!