# A Review of Extruder Automation Systems

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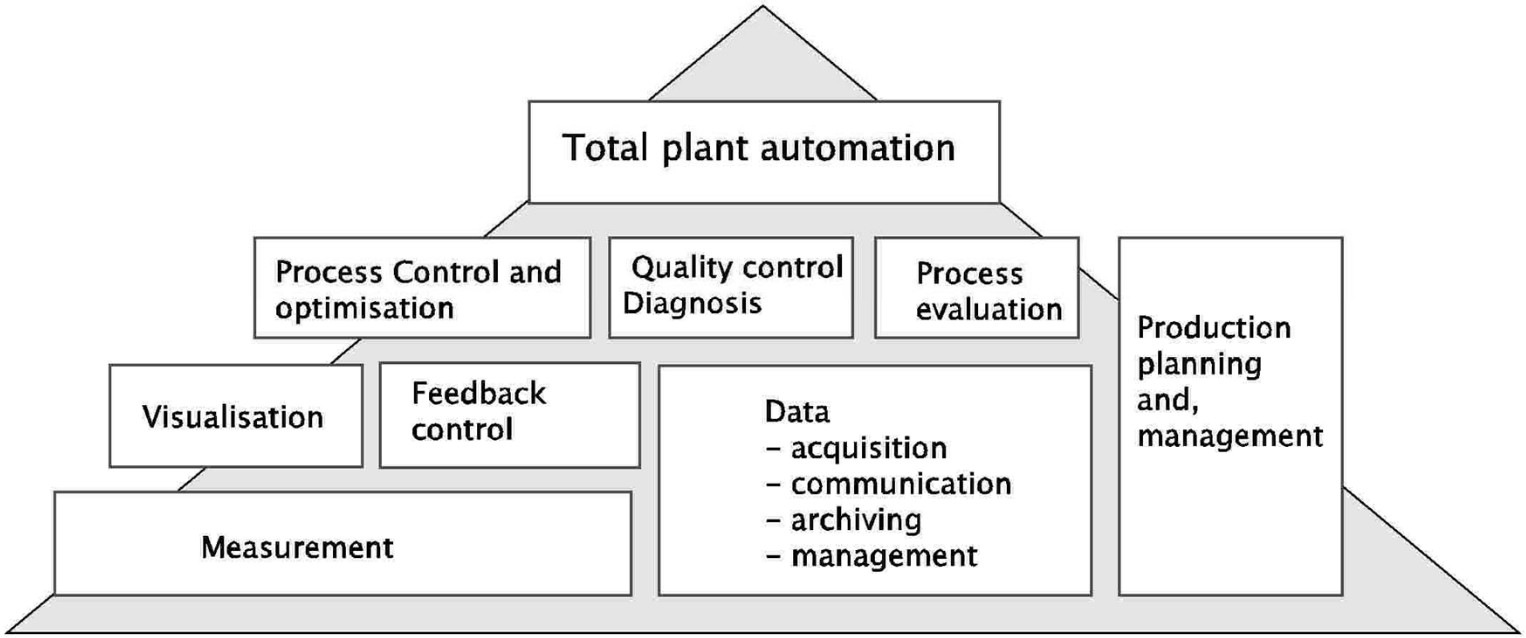
## *AUTOMATION in ALUMINIUM EXTRUDERS*



## *Contents*

## *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** | *Control* |
| ***Extrusion*** | |
| **Ram movement** | *Control* |
| **Profile temperature** | *Control* |
| ***Profile Handling*** | |
| **Assess profile properties** | *Image processing* |
| **Cool profile** | |
| **Puller movement** | *Control* |

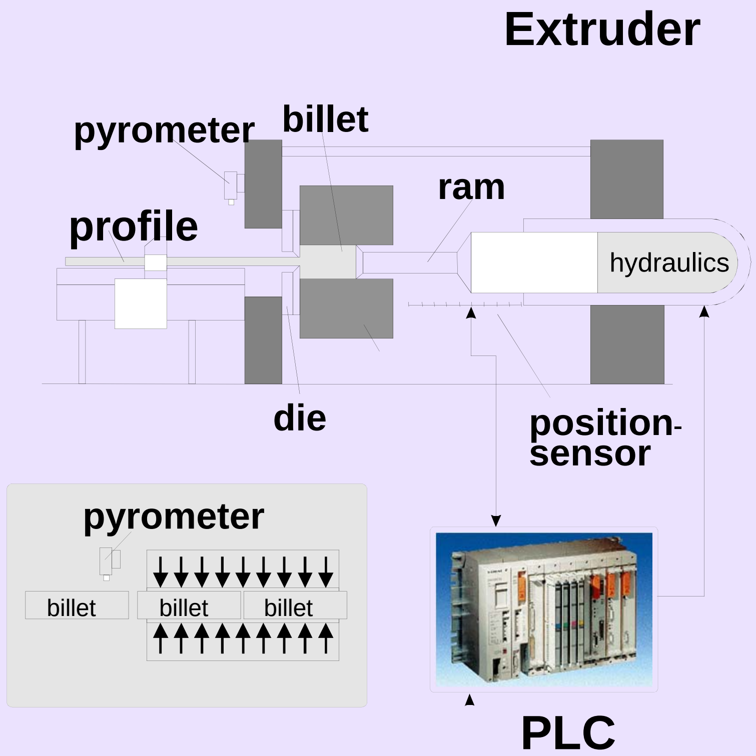
# . . 2. AUTOMATION TASKS to be PERFORMED in EXTRUSION . .

*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***

***Data Acquisition Task***

***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***

***Visualisation Task***

***Control Task***

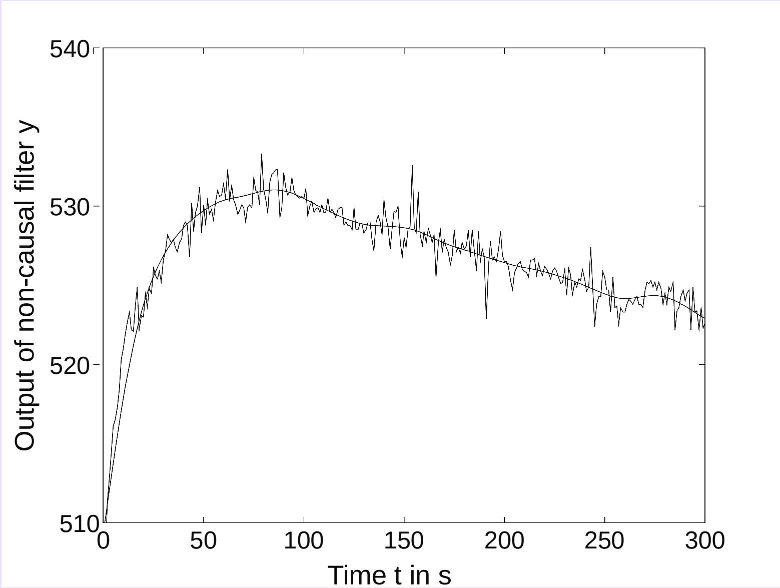
## . . 2. AUTOMATION TASKS to be PERFORMED in EXTRUSION . .

***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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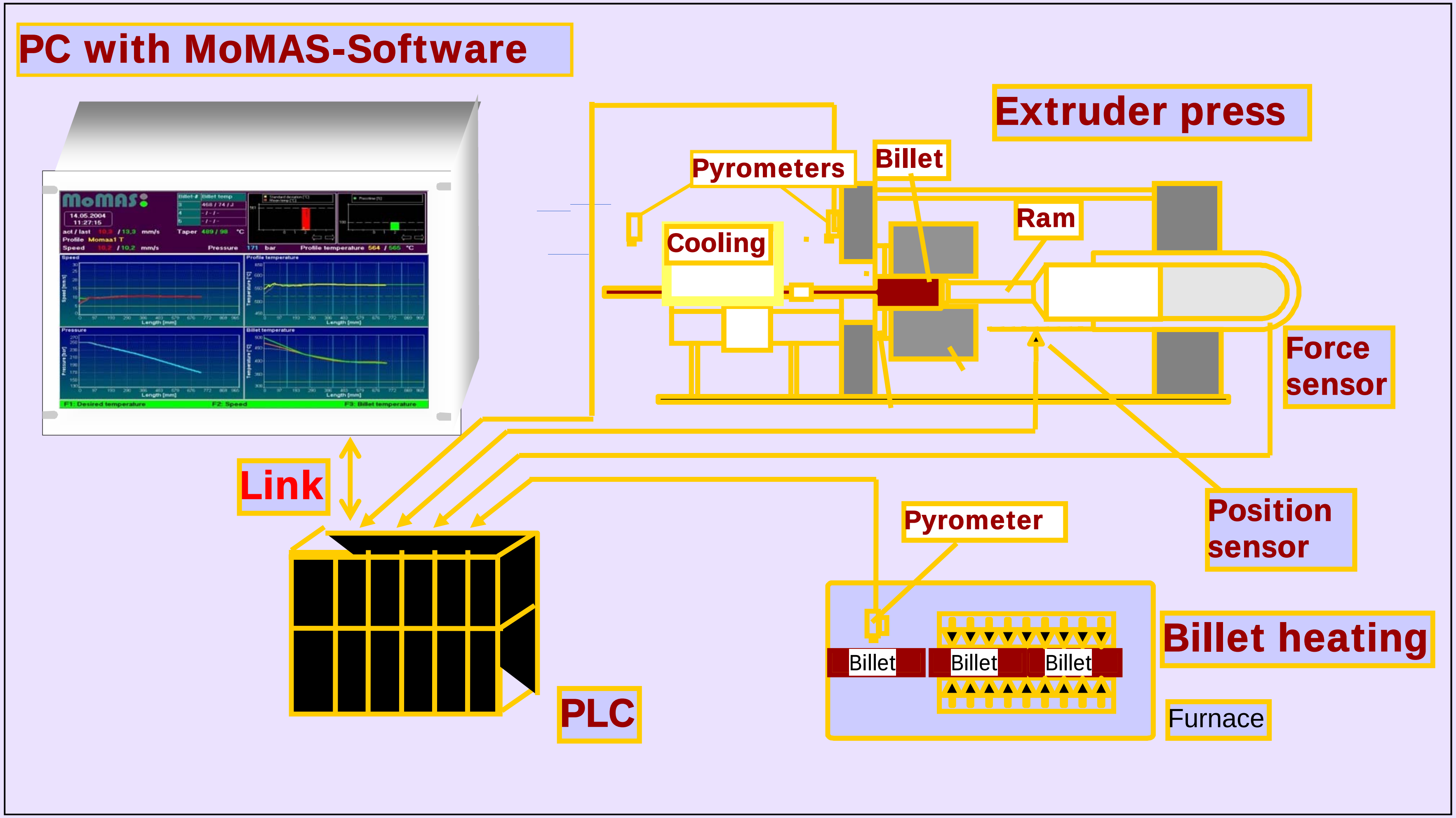
# 3. An AUTOMATION SYSTEM for ALUMINIUM EXTRUDERS . .

MoMAS - **Modular Measurement and Automation System**



### Learning algorithm

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

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

with:

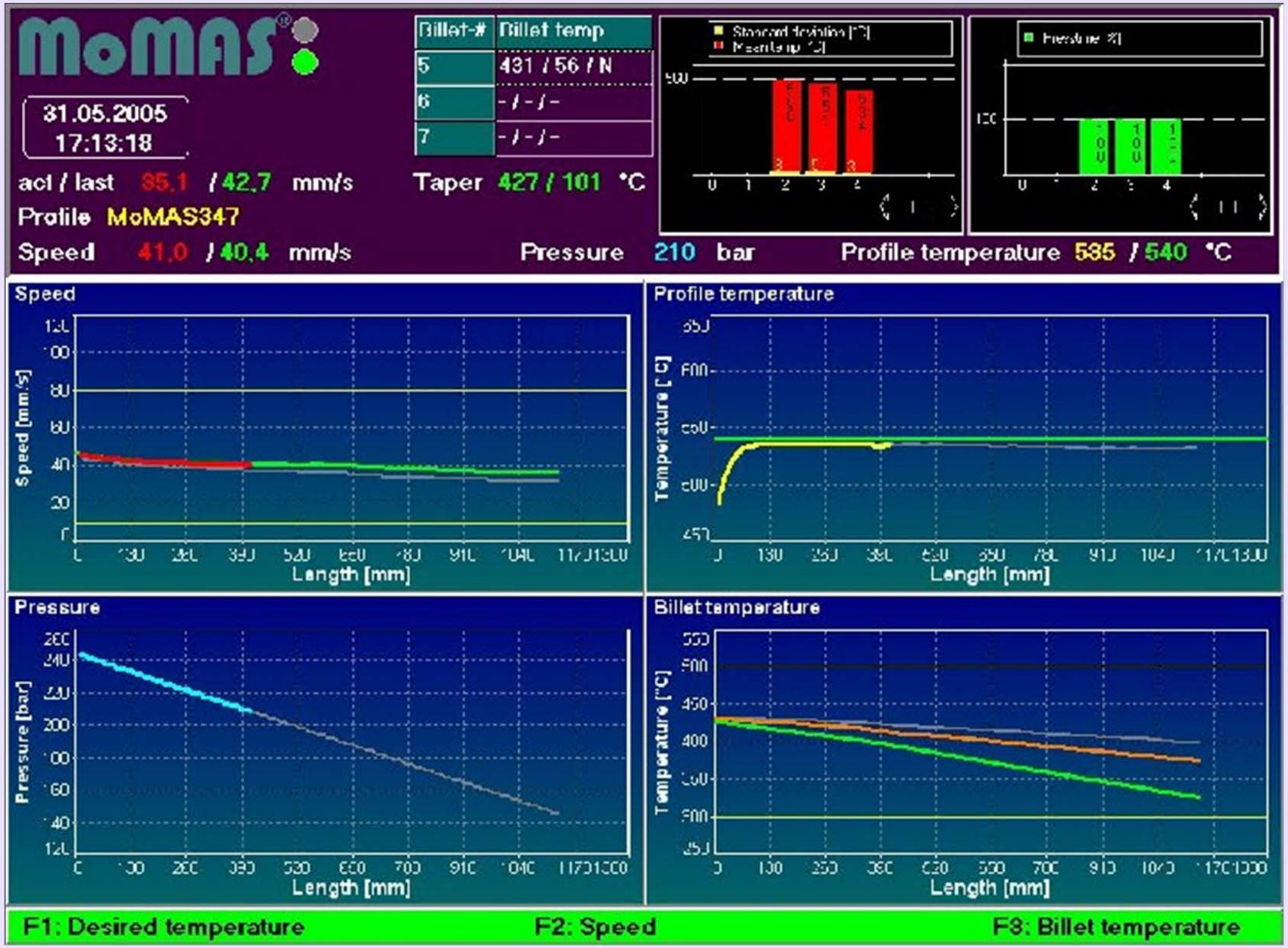
| | | |
|---|---|---|
| $\vartheta_d(l)$ | : | Desired run of exit temperature |
| $u_k(l)$ | : | Input as a function of extruded length of cycle k |
| $v_k(l)$ | : | Ram velocity in current cycle k |
| $\vartheta_k(l)$ | : | Run of exit temperature in previous cycle k |
| $\Delta u_{k+1}(l)$ | : | Increment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

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

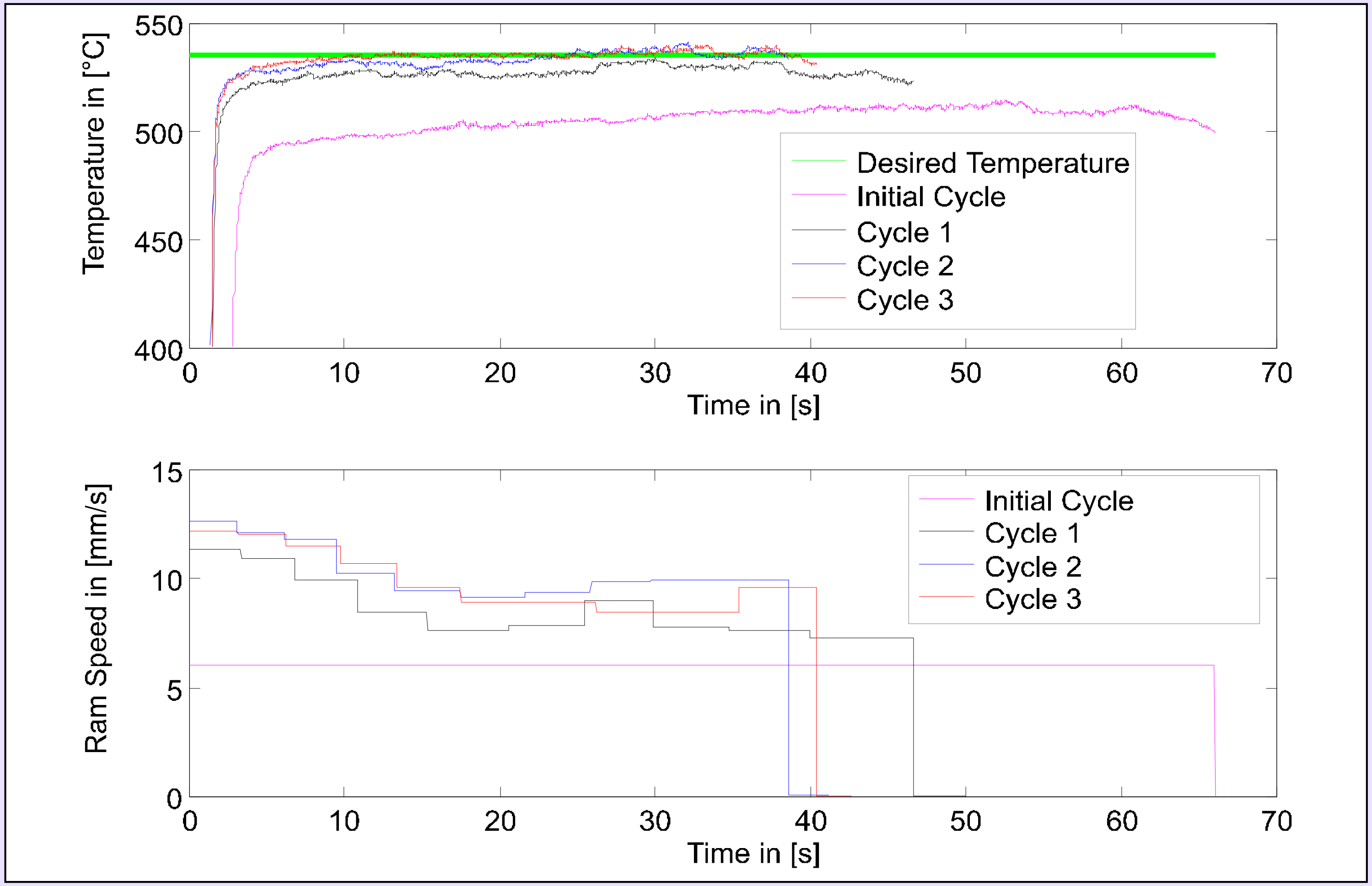
***With exact model convergence to optimal input in 1 cycle !***

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***

## Contents

## *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*

***University Group + Plant crew : 6 installations (2001 - 2003)***

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

***MoMAS Team + BEC : 4 installations (2007 – 2010)***

***MoMAS Team + RUN Automation : current installations***

info@momas.de

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# 5. EXPERIENCE with INSTALLED SYSTEMS . .

## *Production Statistics of Extruder equiped with MoMAS ®*
## *at SAPA Offenburg*

| | No. of billets extruded | Mean extrusion rate | RMS error of exit temp. $\vartheta$ | Standard deviation of $\vartheta$ |
|---|---|---|---|---|
| With MoMAS | 30 381 | 10.02 mm/s | 12.1 °C | 3.89 °C |
| Without MoMAS | 26 180 | 9.29 mm/s | (28.8 °C) | 4.21 °C |

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

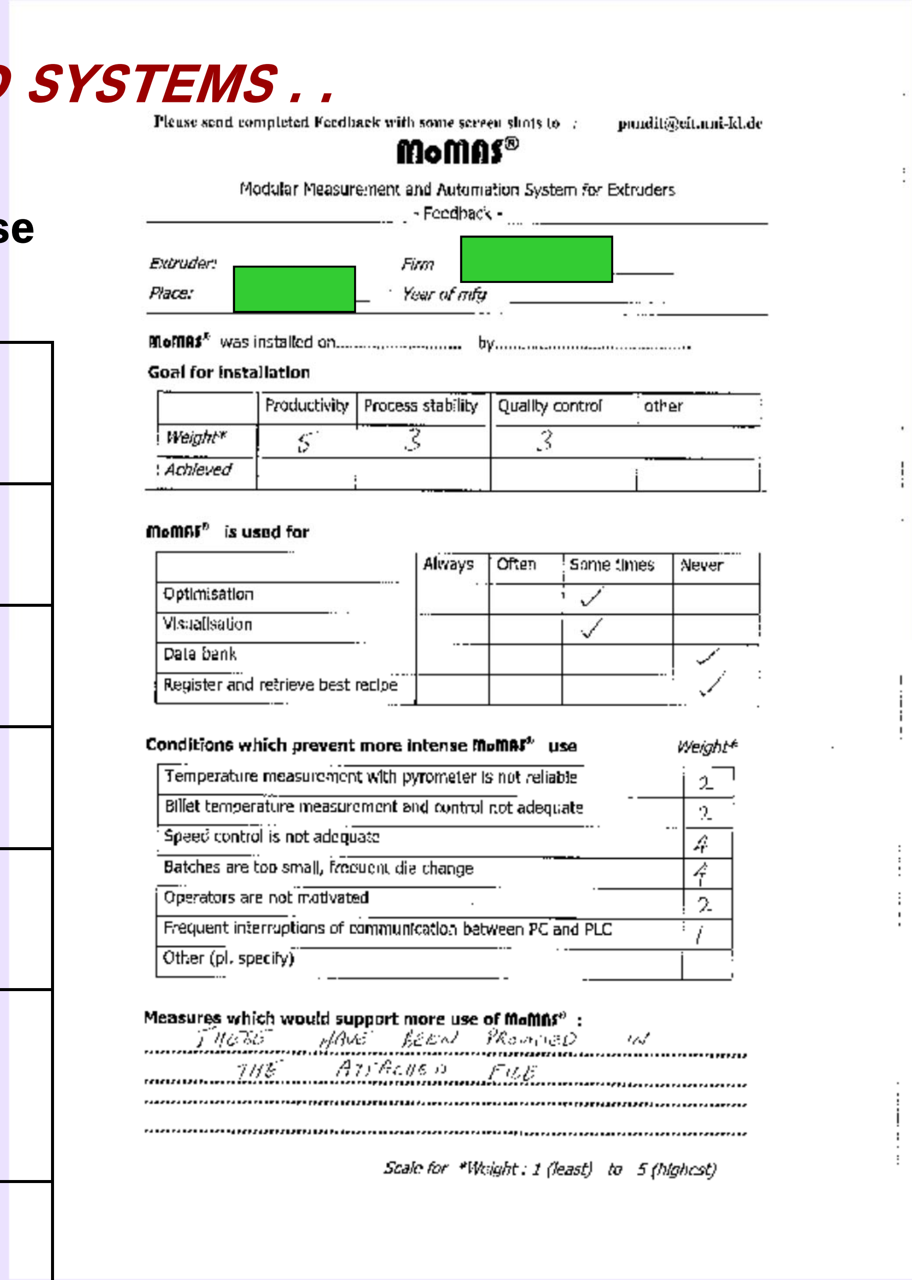
Note increased mean extrusion rate of > 6%

## . . 5. EXPERIENCE with INSTALLED SYSTEMS . .

### *Feedback from plants*

**Weight of conditions which prevent more use**
**1: least important 5 : most important**

| | |
|---|---|
| **Temperature measurement with pyrometer is not reliable** | **2** |
| **Billet temperature stability** | **2** |
| **Operators are not motivated** | **2** |
| **Speed control is not adequate** | **4** |
| **Batches are too small, frequent die change** | **4** |
| **Frequent interruptions of communication between PC and PLC** | **1** |
| **Other (pl. specify)** | |



Please send completed Feedback with some screen shots to : pandit@eit.uni-kl.de

**MoMAS®**

Modular Measurement and Automation System for Extruders
- Feedback -

*Extruder:* *Firm*
*Place:* *Year of mfg*

**MoMAS®** was installed on........................ by........................................

**Goal for installation**

| | Productivity | Process stability | Quality control | other |
|---|---|---|---|---|
| *Weight** | 5 | 3 | 3 | |
| *Achieved* | | | | |

**MoMAS®** **is used for**

| | Always | Often | Some times | Never |
|---|---|---|---|---|
| Optimisation | | | ✓ | |
| Visualisation | | | ✓ | |
| Data bank | | | | ✓ |
| Register and retrieve best recipe | | | | ✓ |

**Conditions which prevent more intense MoMAS® use** *Weight**

| | |
|---|---|
| Temperature measurement with pyrometer is not reliable | 2 |
| Billet temperature measurement and control not adequate | 2 |
| Speed control is not adequate | 4 |
| Batches are too small, frequent die change | 4 |
| Operators are not motivated | 2 |
| Frequent interruptions of communication between PC and PLC | 1 |
| Other (pl. specify) | |

**Measures which would support more use of MoMAS® :**
THESE HAVE BEEN PROVIDED IN
THE ATTACHED FILE

*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.**

## . . 5. EXPERIENCE with INSTALLED SYSTEMS . .

**... 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**

## *. . 5. EXPERIENCE with INSTALLED SYSTEMS . .*

**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 !