Efficiency Optimization of the Aluminum Extrusion Plants

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ABSTRACT – Through research and development, studies focused on the reduction of energy consumption of extrusion equipment have been done. These approaches are typically structured in two steps: in a first step, it is important to know the actual consumption of a single unit (e.g., a motor); this can be accomplished by installing software that can register the consumption of each motor. A second step focuses on the study of main system improvements. Main systems are defined as follows: the log furnace, the puller, the cooling system, the cold saw, and the die cleaning equipment. In each case, new solutions and technical devices have to be considered in order to improve the global efficiency.

REDUCTION OF THE ENERGY CONSUMPTION OF AN EXTRUSION LINE (FEEDLINE AND HANDLING SYSTEM)

Extensive resources have been dedicated to the study of the energy consumption of the main machines of an extrusion line, both for the feed line and for the handling system.

1.0 CONSUMPTION MONITORING AND CONTROL SOFTWARE

The integrated software allows tracking for each lot of extruded product, including all production data and consumptions (electric energy, gas, water, etc.).

Complete traceability and knowledge of all the processing data for each lot permits:

1) Improvement of the quality of the products and the guarantee of the technical features;

2) Planning of a preventive maintenance program, which assures longer life and higher efficiency of the equipment; for example, if increases in energy absorbed by a machine are seen, it indicates that regulations of its operating parameters would be required;

3) Highlighting of operating points where energy consumption is elevated, and where possible improvements can be applied in order to reduce the cost of the product;

4) Knowledge in detail of production costs for each single lot.

Some examples of data provided by the management software are the following: (see Figures 1.1, 1.2, and 1.3)
**Figure 1.1.**

<table>
<thead>
<tr>
<th>MACCHINA</th>
<th>CONSUMO PER LOTTO</th>
<th>CONSUMO PER KG PRODOTTO</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AVANTI PRESSA</strong></td>
<td>1 Kwh</td>
<td>7 m³ gas</td>
</tr>
<tr>
<td><strong>PRESSA</strong></td>
<td>46 Kwh</td>
<td></td>
</tr>
<tr>
<td><strong>TUNNEL</strong></td>
<td>4 Kwh</td>
<td></td>
</tr>
<tr>
<td><strong>CAPPE RAFFREDDAMENTO</strong></td>
<td>1 Kwh</td>
<td></td>
</tr>
<tr>
<td><strong>PULLER/STIRATRICI</strong></td>
<td>20 Kwh</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MACCHINA</th>
<th>CONSUMO PER GIORNATA</th>
<th>CONSUMO PER KG PRODOTTO</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FORNI MATRICI</strong></td>
<td>426 Kwh</td>
<td></td>
</tr>
<tr>
<td><strong>DEMINERALIZZATORE</strong></td>
<td>327 Kwh</td>
<td>0 m³ Acqua</td>
</tr>
<tr>
<td><strong>TAGLIERINA/ANCESTATORI</strong></td>
<td>75 Kwh</td>
<td></td>
</tr>
<tr>
<td><strong>FORNI INVECCHIAMENTO</strong></td>
<td>41 Kwh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forno 1</td>
<td>0 m³ gas 0 min</td>
</tr>
<tr>
<td></td>
<td>Forno 2</td>
<td>15 m³ gas 0 min</td>
</tr>
<tr>
<td><strong>DISINCESTATORE</strong></td>
<td>6 Kwh</td>
<td></td>
</tr>
<tr>
<td><strong>IMBALLAGGIO</strong></td>
<td>10 Kwh</td>
<td></td>
</tr>
<tr>
<td><strong>FRIGORIFERI</strong></td>
<td>0 Kwh</td>
<td>0 m³ Acqua</td>
</tr>
</tbody>
</table>
Figure 1.2.
Throughout the years, many improvements have been made mostly on the maintenance and productivity side, but only a few studies have focused on energy efficiency. Nevertheless in recent years, log furnaces have achieved significant gains and can now yield efficiencies of more than 65 percent.
2.1 REDUCING THE INTRODUCTION OF OUTSIDE AIR

- Improved thermocouple gate
- Improvement of the doors at the entry and exit zones
- Air curtains in the exit zone of the furnace with the recirculation system of a part of the combustion fumes to reduce the entrance of the outside air, and the exit of the heat.

2.2 EXTERNALLY SUPPORTED ROLLERS WITH HIGH TEMPERATURE BEARINGS

- Reduction in maintenance costs, since these bearings have on average a three-year life span
- Reduction of the installed power and energy consumption, since the dissipations due to friction during the billet movements are reduced.

With a traditional roller conveyor for 9" logs, 18.5KW are used to power the log pusher. In addition, the cylinder, which pushes the log back into the furnace, normally works at an operating pressure of 120 bar. A modern furnace with external roller operates at 11KW for the pusher, and 50 bar for the cylinder.
2.3 REFRACTORY DESIGN WITH TWO-LAYER SYSTEM

Advances in refractory design and fabrication allow a better thermal insulation of the furnace walls and roof. Refractory blocks are now based on an integrated design that provides a better thermal seal between elements. Also the overall thickness of the refractory has been increased by 20 percent. Pre-cast blocks form the crown piece. This allows an improvement in the furnace structure and guarantees a better seal between sections of refractory elements, thus reducing air spaces and the need for layers of ceramic fiber matting to insulate joints.
2.4 UPGRADED HEAT EXCHANGER CAPABLE OF REACHING 300°C AIR TEMPERATURE AND BETTER FLAME QUALITY IN THE BURNER ZONE

2.5 CONTINUOUS REGULATION OF THE COMBUSTION RATIO ACCORDING TO THE TEMPERATURE OF THE COMBUSTION AIR

A highly efficient furnace must have continuous feedback control and a control system for the volumetric flow of gas based on a function of the temperature of the combustion air.

- **BETTER ENERGY EFFICIENCY**: Stochiometric control allows higher temperature flames and leads to a decrease in excess of air. The overall result is a high performance log-heating furnace.

![Graph showing energy efficiency and emissions](image)

Figure 2.8.

This graph above shows that in case of a flue gas temperature equivalent to 600°F (315°C), an excess of air of 20 percent causes a loss of approximately five percent, while a deficiency of air of 20 percent causes a loss of 20 percent.

- **REDUCED EMISSIONS**: by preventing the log-heating furnace from running with a deficiency of combustion air, it becomes possible to reduce CO generation.
2.6 FORCED PREHEATING OF THE LOG

Forced pre-heating includes jet nozzles that recirculate the exhaust fumes produced from the burners, and convey them perpendicularly to the log axis: with this solution, a better thermic exchange and better efficiency output can be attained, compared to the same consumption of a traditional furnace. As a result, it is possible to reduce the furnace length by 20 percent.

Figure 2.10.

These innovations reduce the energy consumption up to the following values:

<table>
<thead>
<tr>
<th>SPECIFIC CONSUMPTIONS</th>
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<tbody>
<tr>
<td>GAS (CH4: Pc inf= 8340 kCal/Nm³)</td>
<td>200 Kcal/kg</td>
</tr>
<tr>
<td>ELECTRIC ENERGY</td>
<td>0.01 kWh/kg</td>
</tr>
</tbody>
</table>
3.0 PULLER

OMAV has pioneered a puller system with an on-board drive unit. The movement occurs through a brushless motor and rack-pinion system. Due to this new drive system, it is possible to substantially reduce weight and friction. The disadvantages of elastic cables or chains are completely eliminated.

1) **IMPROVEMENTS IN THE PRODUCT QUALITY**: the elimination of a traditional drive system by chain allows reduction of both inertia and friction. As a result, the puller dynamics are faster and more responsive. It is possible to extrude profiles with speed and force applied at a constant rate during the entire extrusion process, which ultimately results in a higher quality extrusion.

2) **REDUCTION OF MAINTENANCE COSTS**: lubrication, tensioning, adjustment, or replacement of a drive chain/cable is no longer required.

3) **REDUCTION OF NOISE**: a helical rack is used to assure constant contact between rack and pinion.

4) **REDUCTION OF INSTALLED POWER AND ENERGY CONSUMPTION**: Reduced mass and friction allow a downsizing of puller drive components.

<table>
<thead>
<tr>
<th></th>
<th>TRADITIONAL PULLER WITH TRANSMISSION BY CHAIN</th>
<th>PULLER WITH TRANSMISSION BY RACK - PINION AND ON BOARD MOTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>PULLING FORCE (Kg)</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>MAX. EXTRUSION SPEED (m/min)</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>MAX. RETURN SPEED (m/min)</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td><strong>INSTALLED POWER (KW)</strong></td>
<td><strong>27</strong></td>
<td><strong>11</strong></td>
</tr>
</tbody>
</table>
4.0 COOLING SYSTEMS

In order to reduce energy consumption and to improve the quality of the extruded product, intensive cooling tunnels are available with systems that allow precise control of cooling rates by measuring and regulating, in a closed loop system, both water spray and air flow. A control algorithm permits one to vary the cooling rate, according to the temperature of the profile at the cooling tunnel exit. The temperature itself is measured by a system of optical pyrometers. For each die, all processing data is registered and stored in a recipe, which can be recalled automatically.

![Cooling system interface](image)

**Figure 4.1.** Cooling system interface.
5.0 COLD SAW WITH DOUBLE BLADE

OMAV has supplied numerous installations of double-blade cold saws. The saws are equipped with two blades, where each blade is dimensioned to cut half of the maximum profile height. The two blades are mounted on independent guiding systems and synchronized in a way that the upper blade cuts the upper half of profile, and the lower blade cuts the lower half. Based on profile height, it is possible to use only one or both blades.

- Improvement in product quality: large diameter saw blades (diameter > 1200mm) can be subjected to considerable oscillations during rotation, which can cause non-perpendicular and poor quality cuts;

- By decreasing the blade diameter it is possible to reduce its thickness, which allows for a significant reduction in chip volume. The economic benefit is doubled, i.e., less scrap and less cost due the recovery of chip;

- Reduction in power consumption, due to the reduced inertia of the blade. Rotational speed can also be reduced quickly between cuts.

<table>
<thead>
<tr>
<th></th>
<th>TRADITIONAL SAW</th>
<th>DOUBLE-BLADE SAW</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRESS</td>
<td>2780 T</td>
<td>2780 T</td>
</tr>
<tr>
<td>BLADE DIAMETER</td>
<td>650 mm</td>
<td>2 x 450 mm</td>
</tr>
<tr>
<td>BLADE THICKNESS</td>
<td>5.5 mm</td>
<td>4.5 mm</td>
</tr>
<tr>
<td>ENERGY CONSUMPTION in Kw/Ton to cut profiles</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>
6.0 DIE CLEANING SYSTEM

Figure 6.1.

Figure 6.2.

The cleaning of extrusion dies is a process, even if confined to the margins of the production process that has an important role and impact on production costs. Typically, die cleaning processes consists of dipping dirty dies in a solution of NaOH with concentration of approximately 30 percent:

\[ 2\text{NaOH} + 2\text{Al} + 2\text{H}_2\text{O} \rightarrow 2\text{NaAlO}_2 + 3\text{H}_2 \]

Until now, this process has been largely considered a support function to the extrusion process with little impact on production costs. Most of the die-cleaning systems installed are very simple, where the chemical reactions take place without any control of process parameters. The following is a list of disadvantages of this approach:

A) **HIGH QUANTITY OF SPENT CAUSTIC SOLUTION:** economical and ecological problems are related to the storage and draining of spent caustic solutions.

B) **UNCONTROLLED OPERATING PARAMETERS:** there is difficulty in controlling both process temperature and hydrogen development. In this case, besides the ecological and production problems, there are also other issues concerning the safety due to potentially explosive mixtures, which could be generated if the concentration of hydrogen exceeds certain limits.

C) **HIGH ENERGY COSTS:** due to the necessity to heat the solutions to trigger the caustic reaction.
In an effort to address the inefficiency of traditional die cleaning systems, integrated systems that operate in full automatic are now becoming the technical standard. Advantages of these systems are as follows:

1) **FULLY AUTOMATIZED SYSTEM**: the system is fully automated, starting from the charging phase of caustic solution, to the unloading of dies. The only operator interaction is the pre-set of the desired caustic concentration and the recipe (time, temperature, type of final rinse).

2) **PRECISE CONTROL OF THE CHEMICAL REACTION**: all parameters of the caustic reaction (temperature, development of hydrogen, concentration of solution, etc.) are monitored and controlled in order to optimize time and efficiency of the process. The process becomes repeatable.

3) **REDUCTION OF NaOH CONSUMPTION**: an automatic system permits continuous monitoring of the aluminum content in solution. This is managed in three different ways:

   - Single etching cycle: "new" solution are always used;
   - Multiple etching cycle: the solution is re-used for the next cleaning cycle;
   - Multiple etching cycle with solution correction: part of the solution is re-used for the next cleaning cycle, after mixing it with a determined percentage of new solution.

   The operator can, based on experience, choose the desired cycle, i.e., he can re-use multiple times the same solution, or part of, in order to considerably reduce the consumption of reagent and the cost of exhausted solution.

4) **ENERGY SAVING**: an integrated system is equipped with a heat recovery system. The heat generated by the reaction is used to preheat the solution for the next cycles. In addition, closed-loop systems re-use cooling and rinse water. Overall efficiency dramatically improves.

5) **SAFETY**: the integrated monitoring of all process parameters allows constant control of the kinetic of reaction, and the resulting emissions. The safety system consists of:

   - Intrinsic safety detector to continuously monitor the quantity of hydrogen
   - PH sensor to measure discharged cooling water
   - Scrubber to clean fumes generated by the caustic reaction
   - Instrumentation and electrical equipment is designed according to ATEX.
7. SUMMARY

With an increase in energy costs, equipment performance becomes a significant factor in overall operational efficiency. Each sub-system should be carefully analyzed, if an extruder wants to produce at minimum cost.

This doesn’t necessarily require high investment amounts. In a first phase, real-time consumption control and monitoring should be implemented. For instance, software-based systems are capable of tracking all relevant production data, and thereby allowing analysis of processing parameters, as well as improvements of all main machines of an extrusion line. In a second phase, extruders may consider upgrades to those systems (e.g., the log furnace) that most heavily impact operating costs.

A modern extrusion line can lower operating costs by more than 30 percent. These gains can be achieved, in addition to the higher pounds per hour rates that a modern press line will yield.