Aluminium extrusions

EXTRAORDINARY POTENTIAL - INFINITE APPLICATIONS - INCREASING TECHNOLOGICAL CONTENT

Event organized by **GMS MILANO** and **A&L Alluminio e Leghe**

APRIL 4TH, 2019

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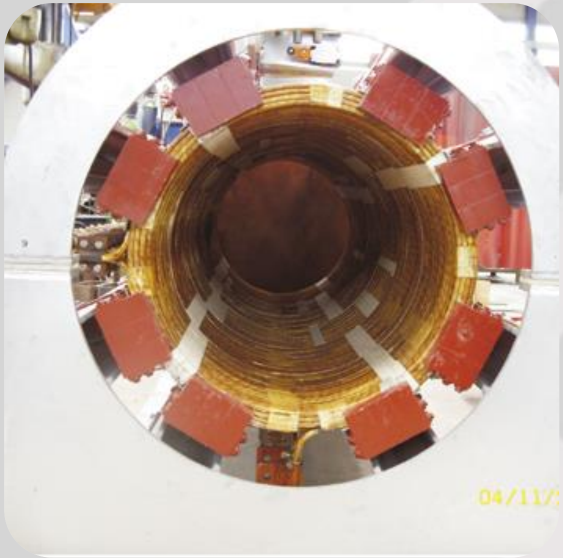
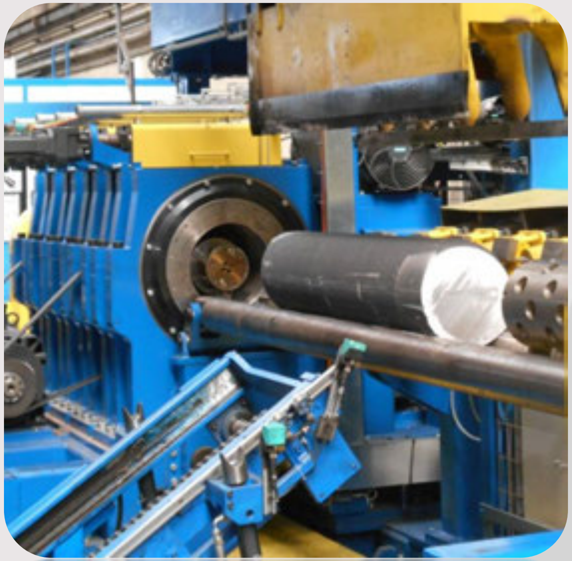
Induction heaters for extrusion technology

The **GMS** coil induction heaters in the Aluminum alloys extrusion process of billets are the most advanced units in this field.

Our systems are equipped with the modern IGBT technology, especially designed, developed and patented by **GMS** with the purpose to create a real flexible and efficient instrument.





HEH

HIGH EFFICIENCY HEATER BY ROTATION OF PERMANENT MAGNETS

DESIGN OF PROTOTYPE

Electro-Mechanical Design

Sizing of the **electro-mechanical system** consists in the choice of **electric motor**s and **related drives**.

- The motors should produce a **torque** that **offset**, in the whole range of operating speeds, the **electromagnetic breaking torque** produced in the billet by the induced electro-magnetic field.
- Considering the give size of the prototype and the general requirements of the problem, **commercial electric motors are adequate** for the machine.
- Since the **range of rotation speed** of magnetic module would lead to a choice of commercial motor too oversized for the application, a system with **transmission ratio 1:2.5** has been chosen consisting of **pulley and drive belt**.

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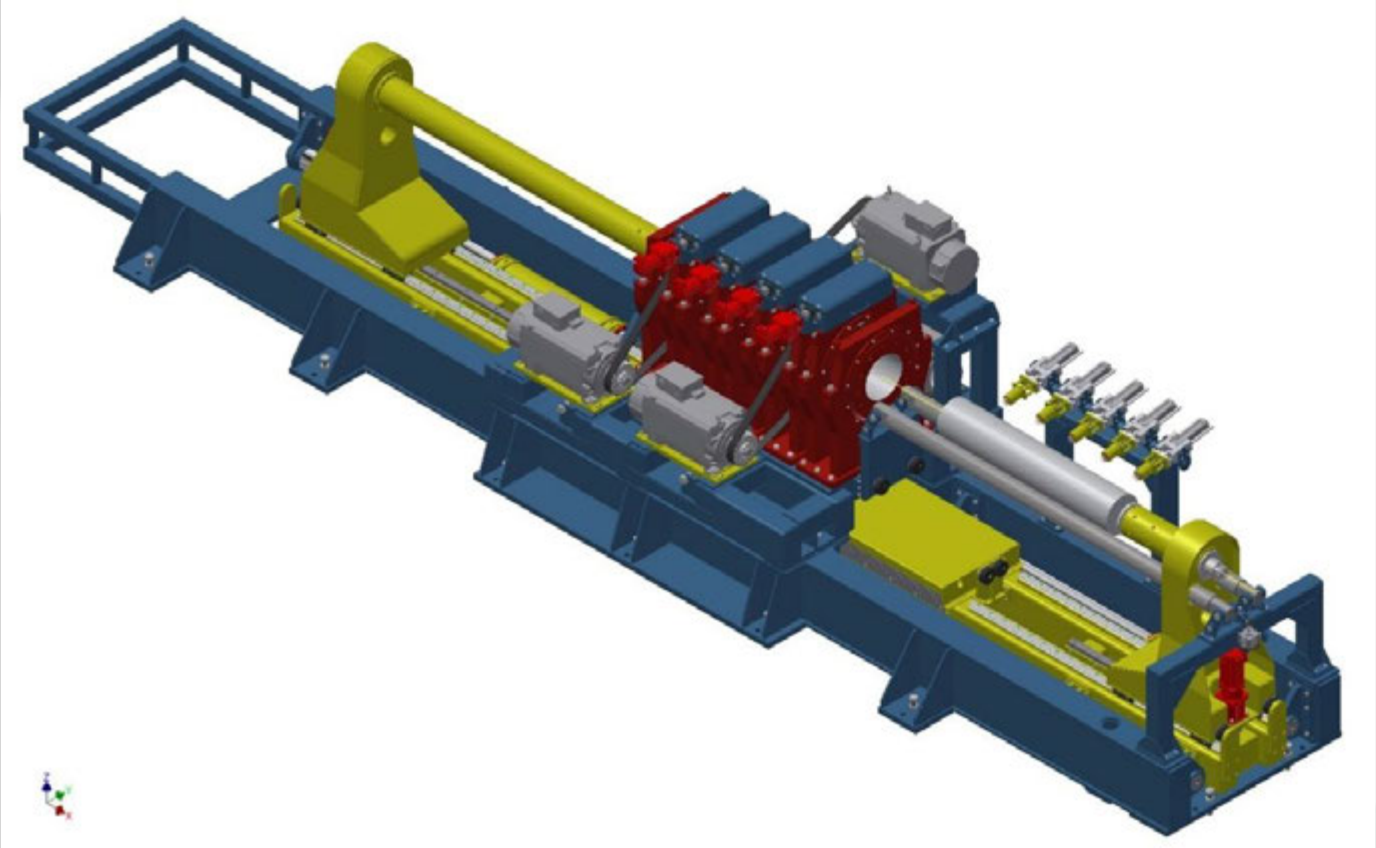
MECHANICAL DESIGN

Main targets of HEH mechanical design

- Maximum efficiency of whole system
- Modern mechanical solution complete assembled on n.1 single frame.
  - Complete pre-commissioning before delivery
  - Easy and precise installation on site
- Limited overall dimensions
- No water cooling plant required
- No hydraulic plant required
- Simple technological Heating system formed by:
  - Heater unit
  - Billet translation device

The HEH heating system is formed by:

- Heater unit
- Billet translation device



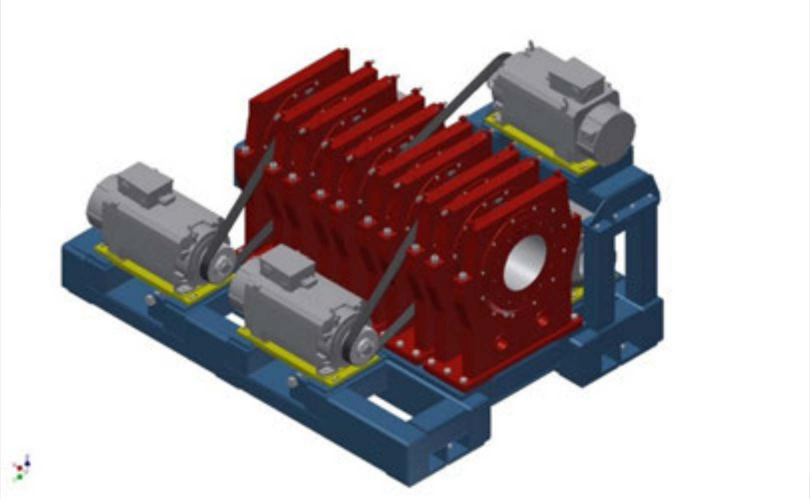
Heater Unit

N.5 independent zones/modules fixed on strong frame

- For constructive simplicity all modules are same each others, and driven by its own electrical motor coupled with inverter unit for speed regulating and torque forces.
- The power installed on each module is suitable for an isothermal heating cycle (maximum power installed required). Simply by regulating the speed of each module we have taper heating.

Each single module is formed by:

- Strong metallic frame
- Rotor body.
- Set of permanent magnet poles
- Set of rolling bearing
- High efficiency timing belt drive
- Brushless electrical motor
- Set of lateral clamping device



It’s foreseen an automatic distribution grease plant in order to reduce maintenance activities.

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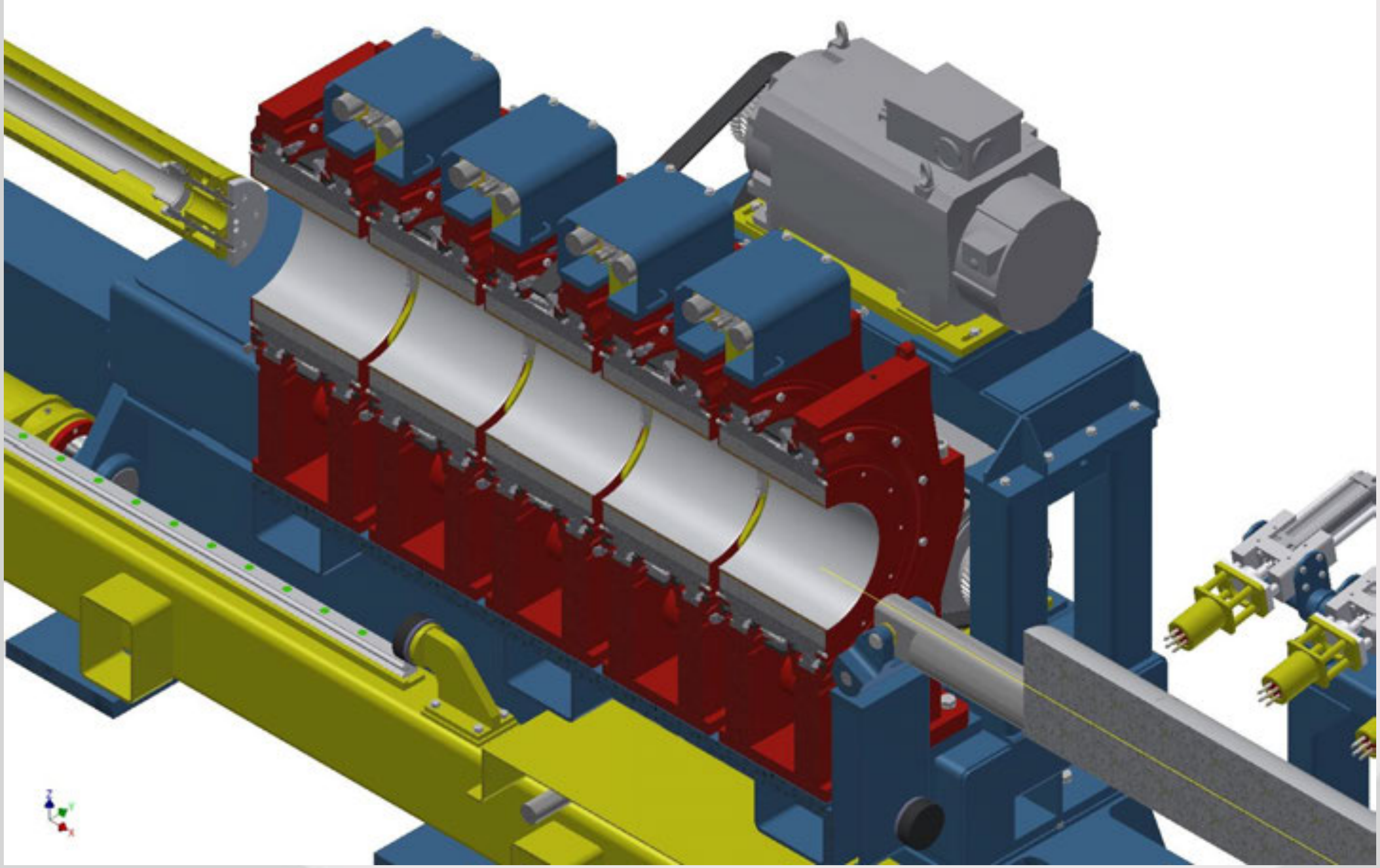
Section of Heater Unit



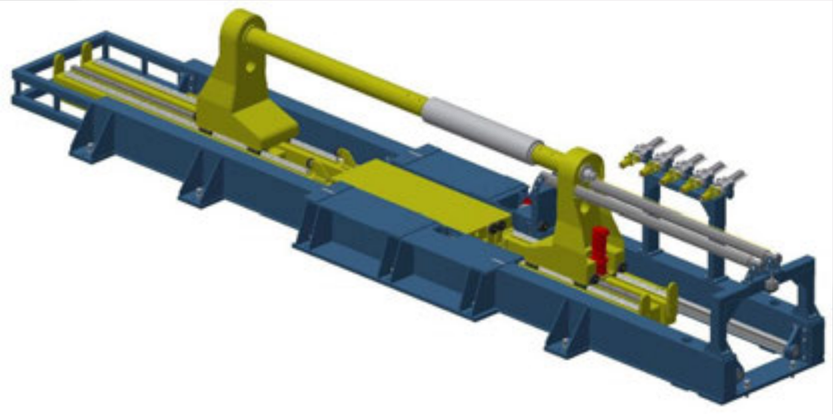
Billet Handling Device

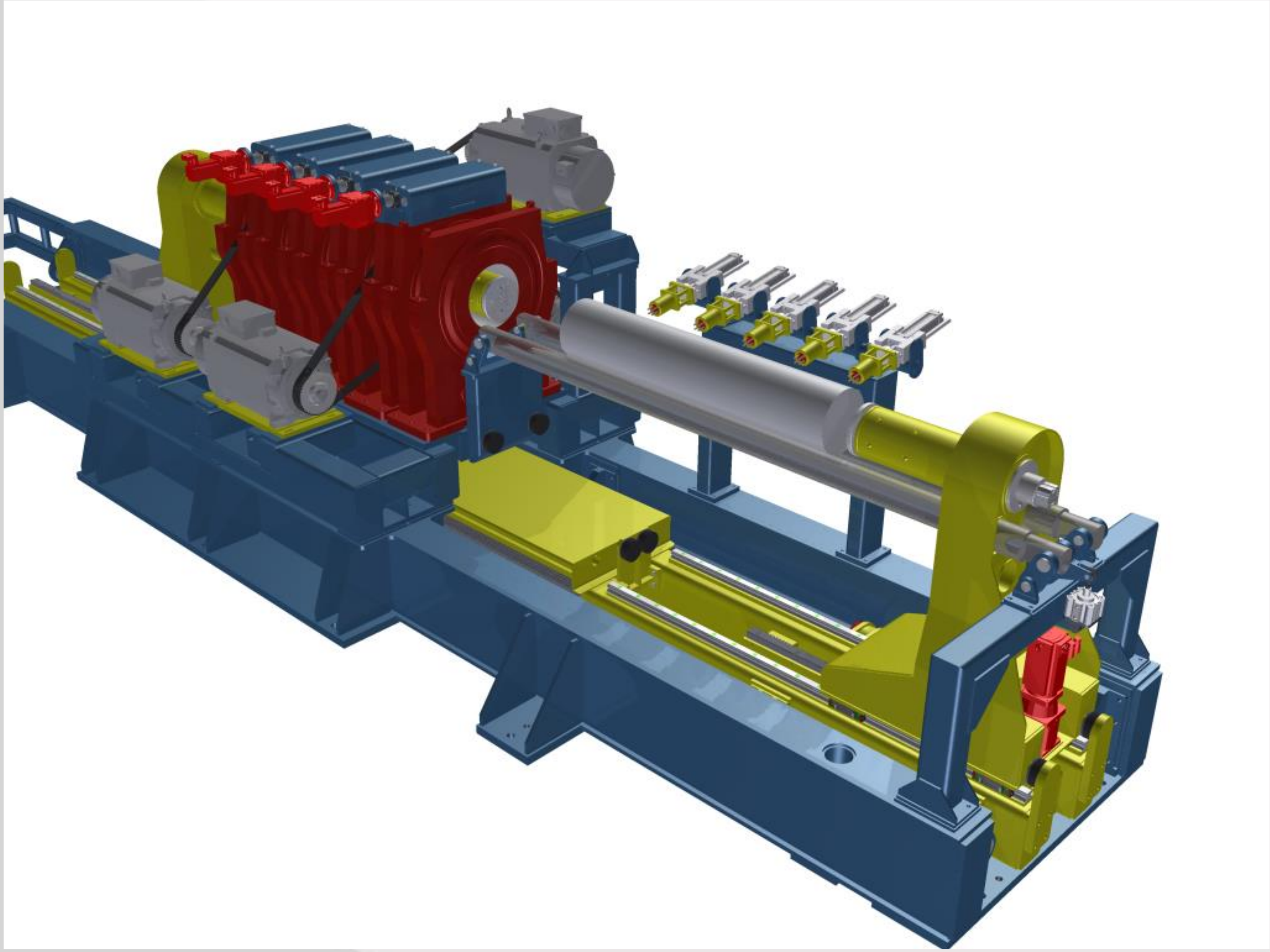
Special billet translation unit designed according to Pandolfo requirements for a correct coupling with existing billets handling system.

- The purpose of this unit is to bring the billet from inlet side and move it inside the heater for heating operation.
- During translation and heating cycle the billet is suspended.

The unit is formed by:

- N.1 Strong metallic frame fixed on the floor
- N.1 Support billet device with pneumatic vertical movement
- N.1 Intermediate translation frame operated by brushless gear-motor to allow precise billet introduction into heater
- N.2 independent movable carriages operated by brushless gear-motor to allow the handling of the billet between heads
- Thermocouples units





SUPERVISOR SYSTEM

Design of control and supervisor system

The design of control and supervisor system has been done through hardware components and the relative managing software that permit to control the devices, the data acquisition on the heating process, exchange of information between different devices, set-up of whole machine.

In particular have been developed the following automated function managed by a PLC and operator HMI:

- **Monitoring of input and output temperature**
- **Managing of motors and relative drives**
- **Command of the loading-unloading system of billets**
- **Monitoring of energy consumption**

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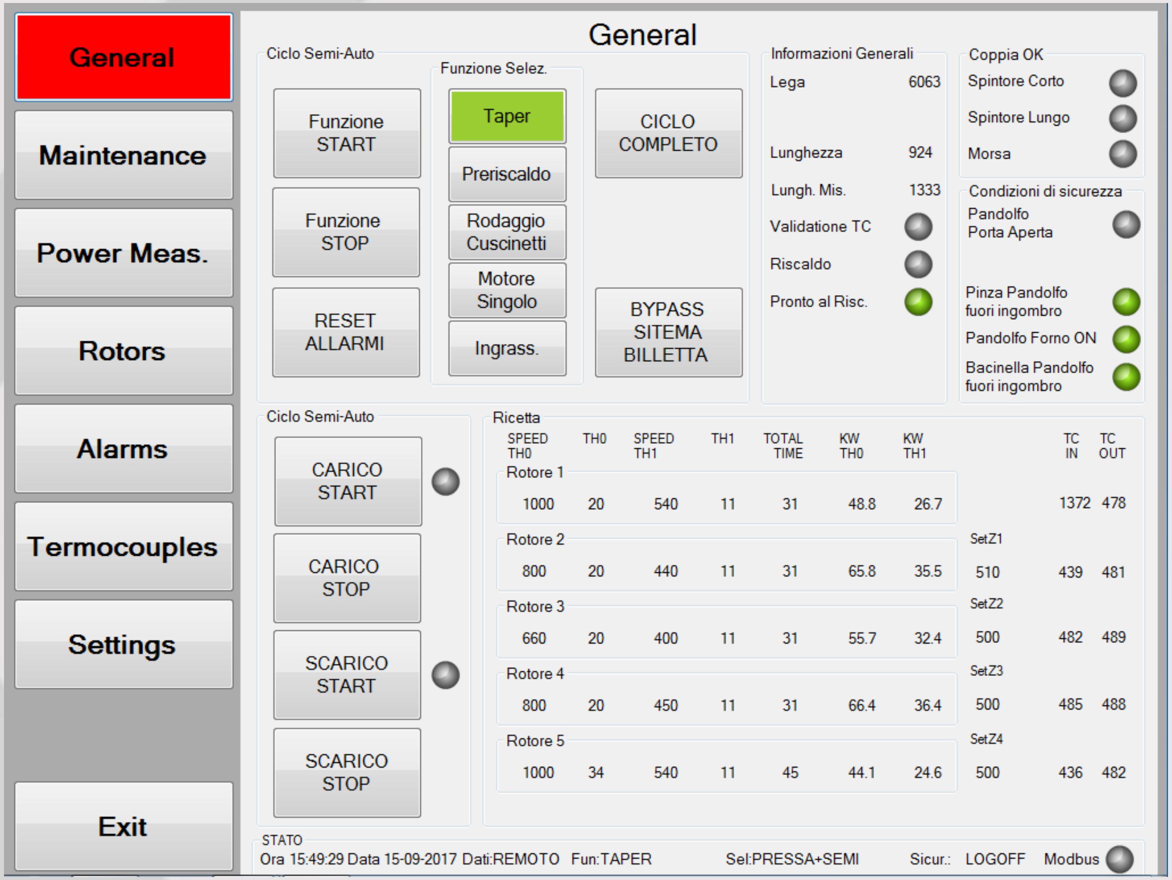
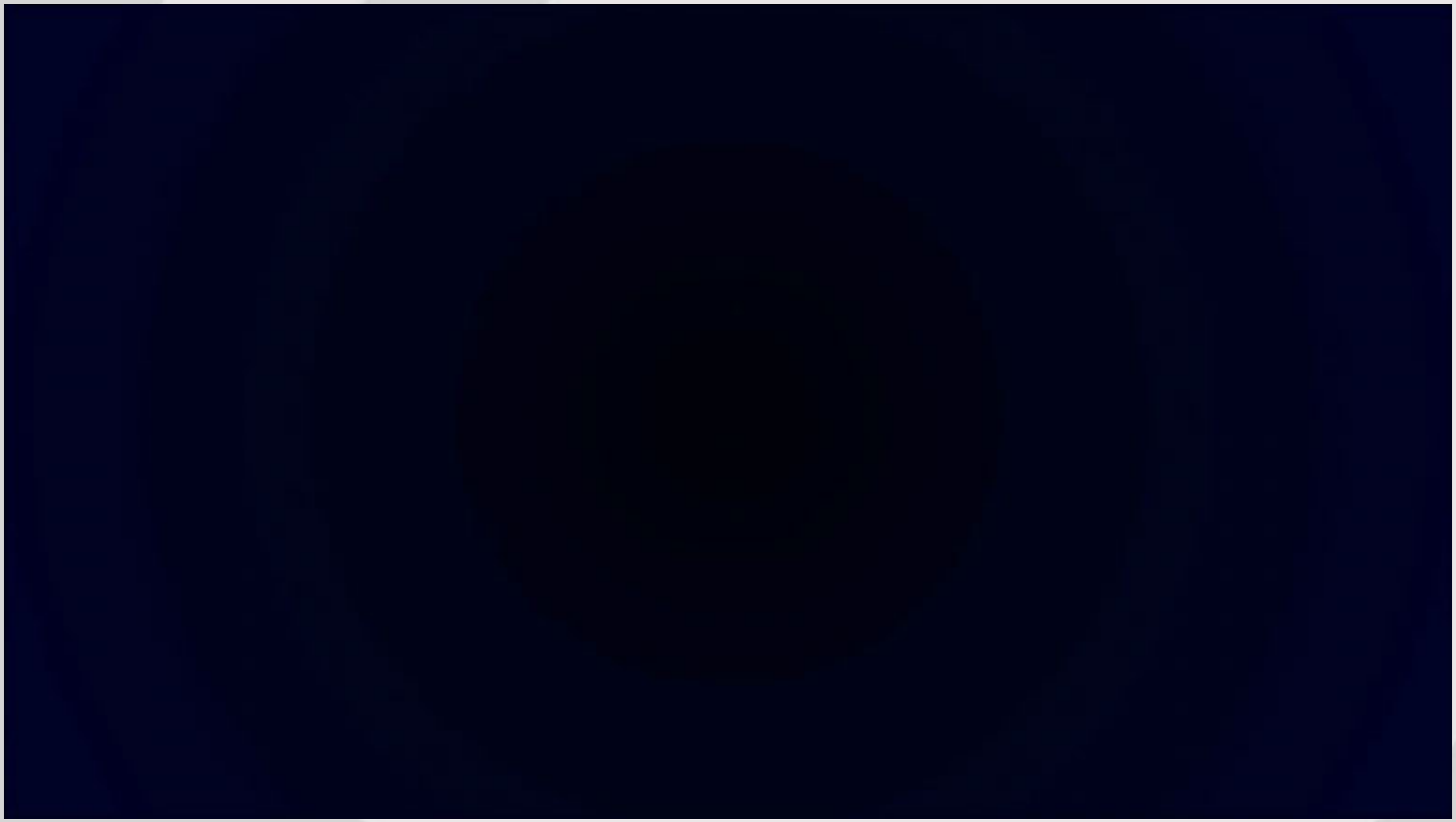
Software interface developed for HMI



Animation of heating cycle



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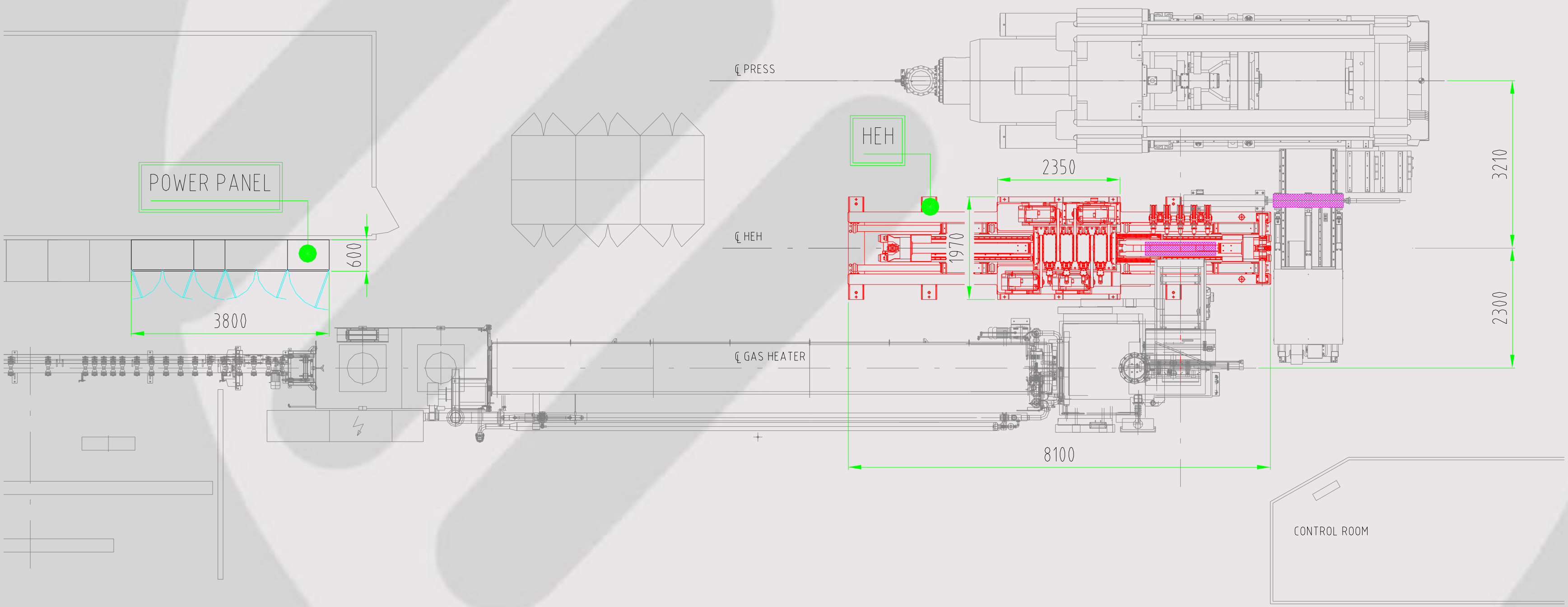
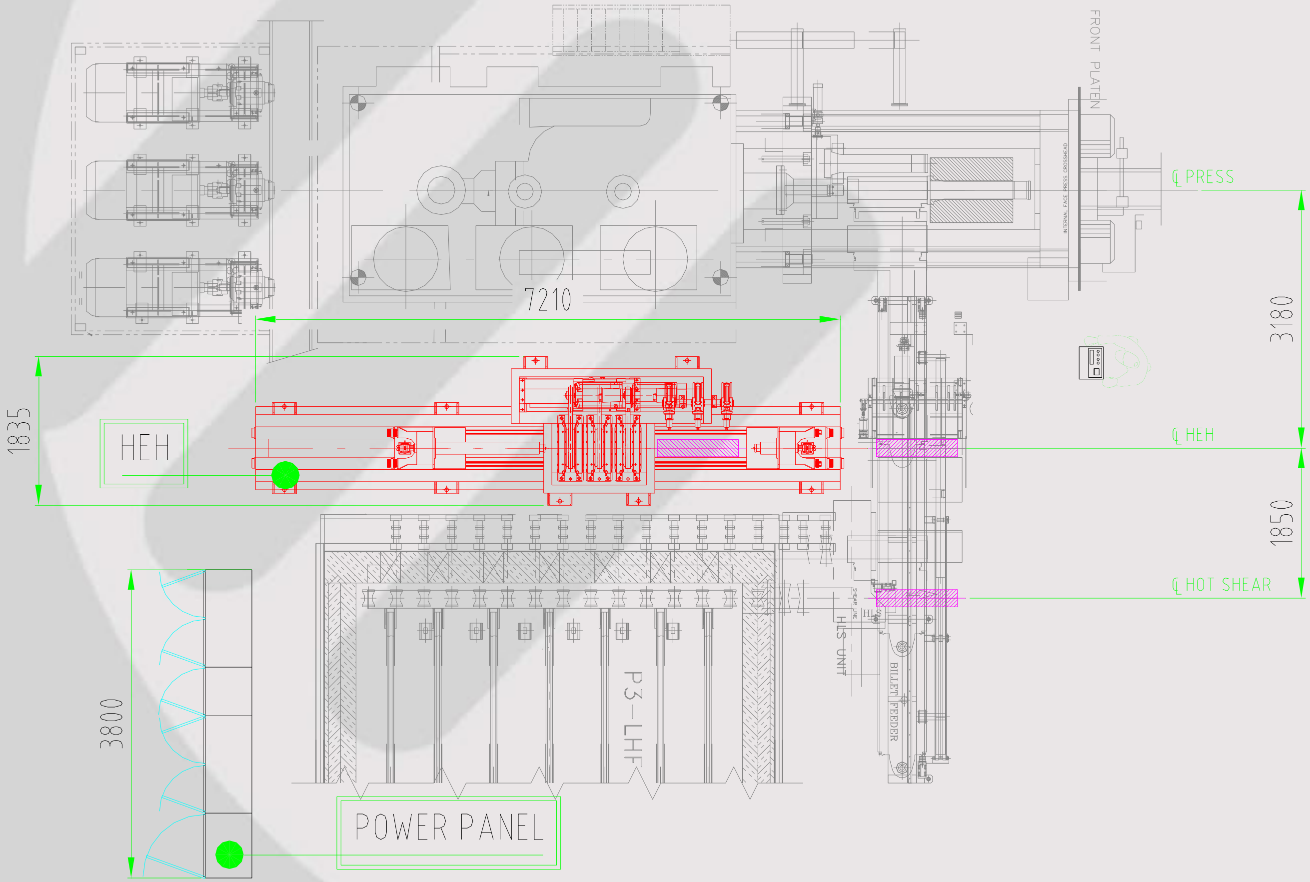
GENERAL LAYOUT
AND
INSTALLATION

General Lay Out



General Lay Out



Installation of HEH

After the off line tests session the existing traditional induction heater has been removed, and HEH heater was installed.

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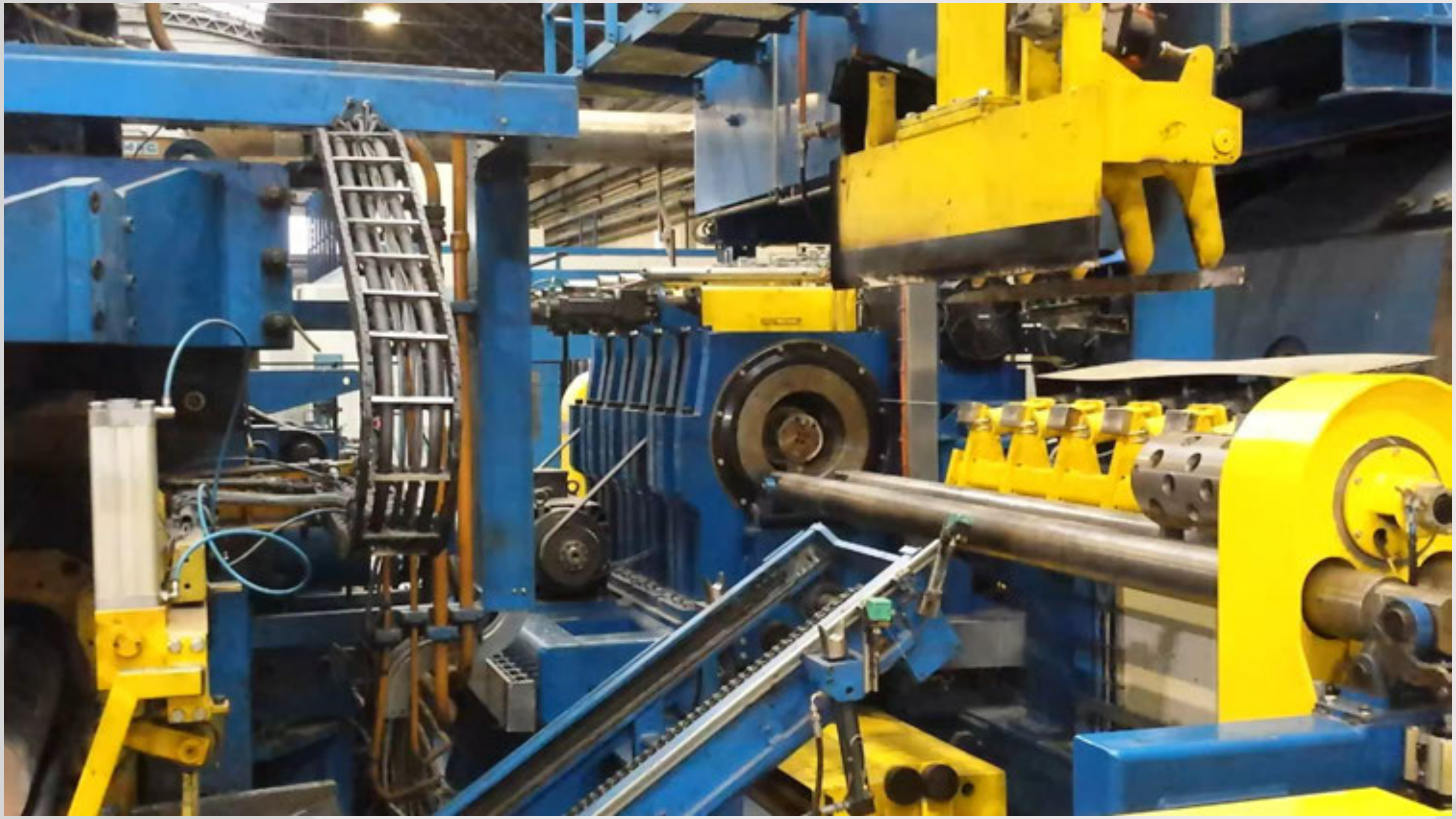
HEH taper heating cycle



PRODUCTION RESULTS

Production Tests

The purpose of **production tests** was to **demonstrate** that the new induction heater, in addition to consuming **less electric power** than the **traditional heater** at the same ΔT, would be able to heat the billets correctly at various lengths, ensuring the necessary productivity for the extrusion press without causing losses due to billet delivery delays or waste.

To allow **statistical analysis** on a significant data volume, a special **SQL Server database** was created to record **all significant parameters** for each heating cycle. In this way it was possible to **check the consumption** and the **correct heating process** by analyzing a large volume of data.

Through the data collection, it was possible **to compare** the **consumption of electricity** with the **traditional induction heater** and with the **HEH heater**.

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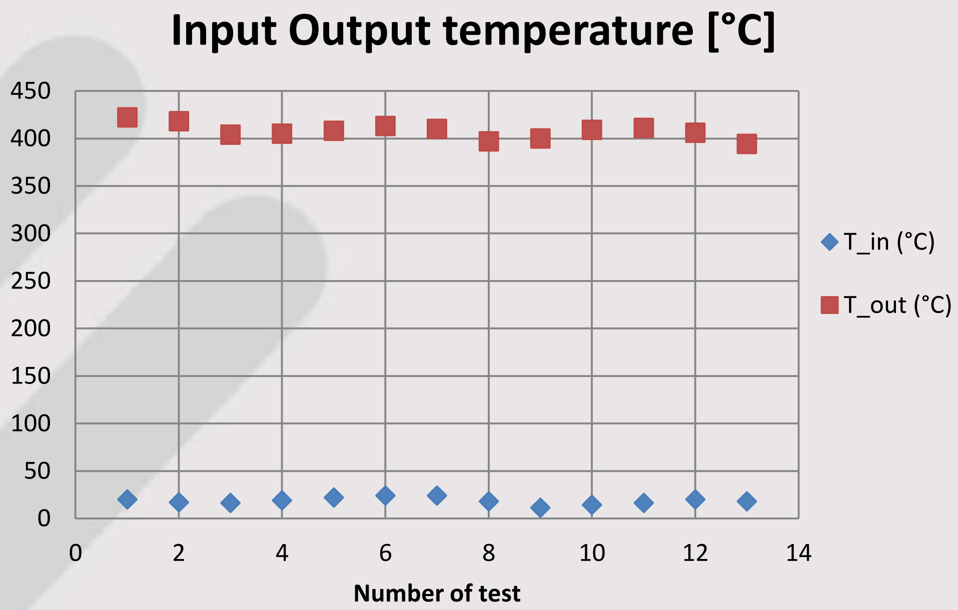
Heating from ambient temperature up to 400°C

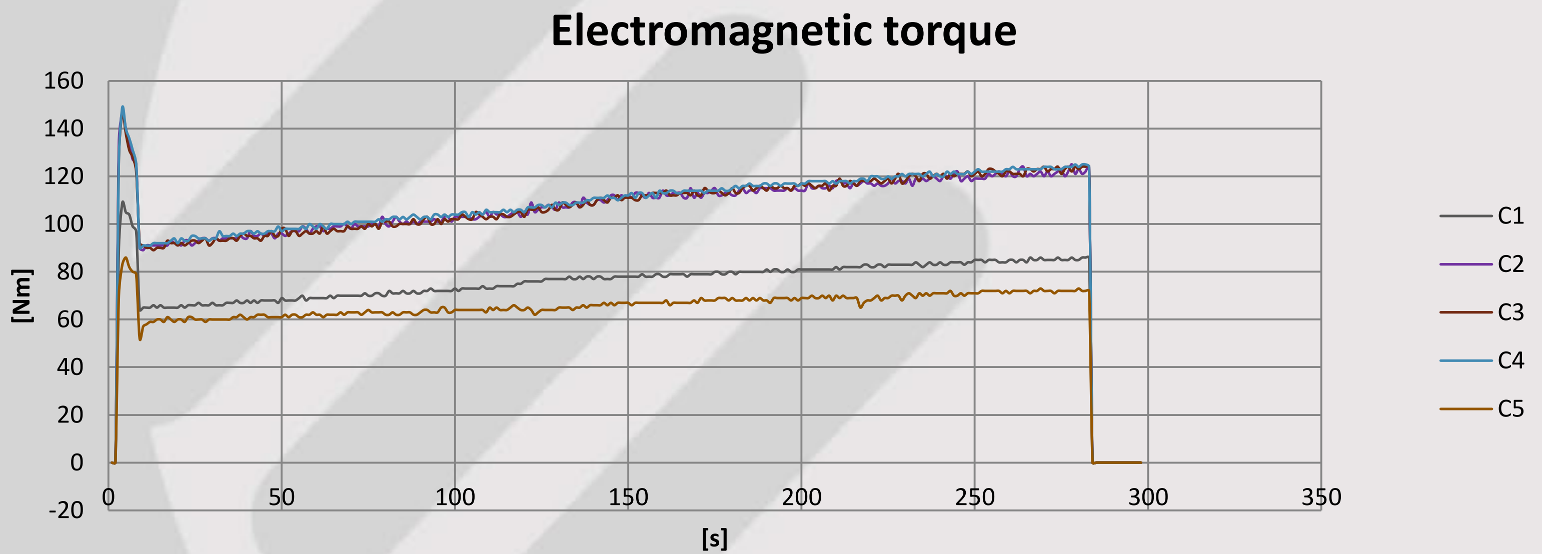
n test	T_in (°C)	T_out (°C)	η
1	20	422	83,8
2	17	418	82,9
3	16	404	80,9
4	19	405	81,1
5	22	408	79,8
6	24	413	81
7	24	410	81,1
8	18	397	80,2
9	11	400	78,9
10	14	409	80,5
11	16	411	80,9
12	20	406	78,5
13	18	394	77,4



<u>Note</u>: the increase of temperature is about 400 °C so the efficiency estimated from the driver to the billet is about 80%. If we consider also the electrical drive and the auxiliary parts, the overall efficiency is about 73%.

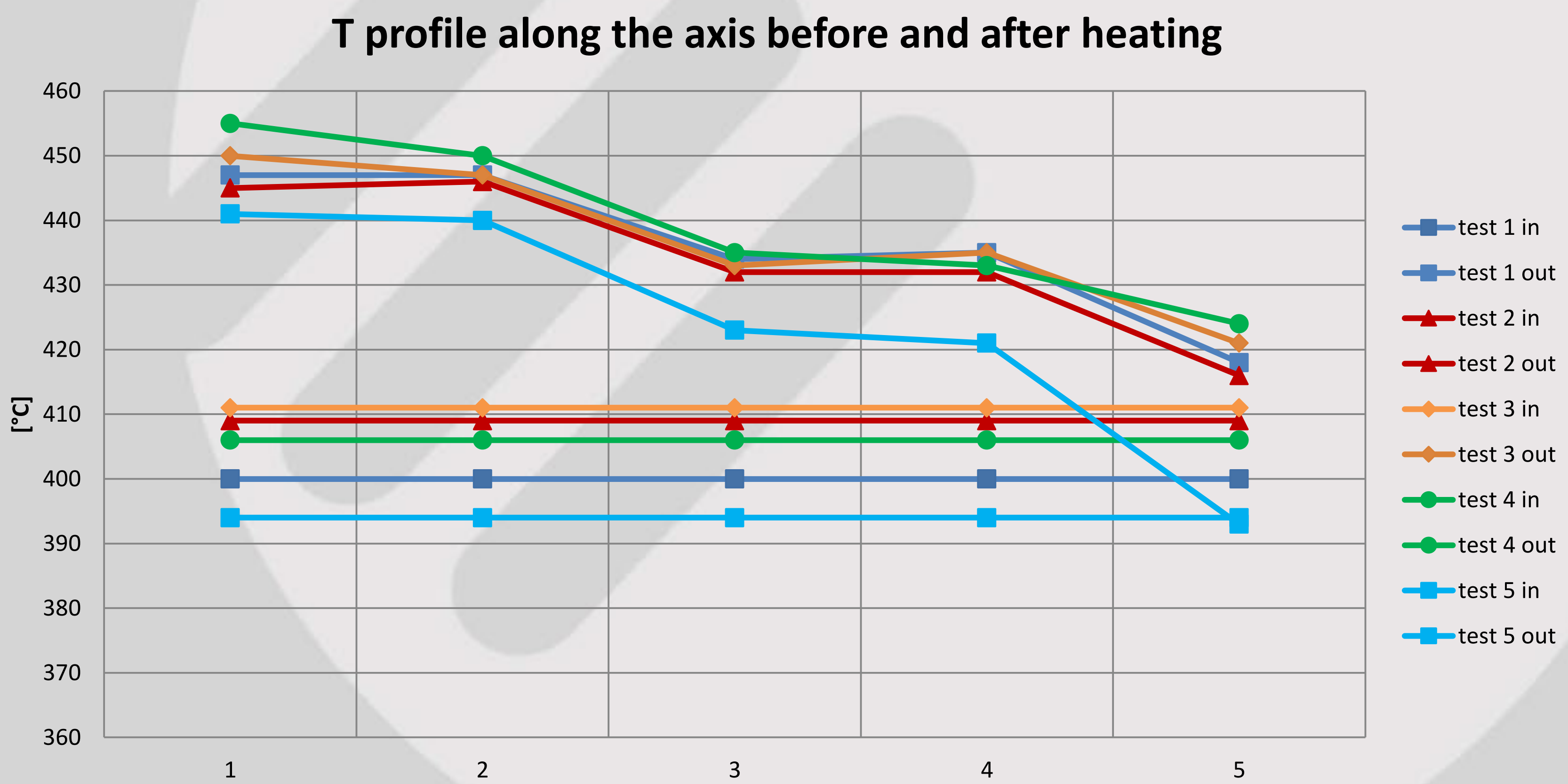
The energy consumption for a uniform heating with an increase of Temperature of 400°C is 135 kWh/ton.

Electromagnetic Torque in the 5 magnetic modules



Note: the electromagnetic torque developed in the module 2-3-4 is equal because they are completely filled by the billet. The torque developed in the modules 1 and 5 (the external ones) is lower because they are not completely filled by the billet. The torque is increasing during the heating process because the temperature and consequently the resistivity of Aluminum are increasing (the rotational speed is constant) .

Taper heating by rotating the magnetic modules at different speeds



KPI (Key Performance Indicators) analysis

The **Key Performance Indicators** (KPIs) chosen to quantitatively assess the performance of the prototype are mainly subdivided in **n.5 classes**:

1. **Indicators of process technical quality**
2. **Indicators of extruded quality**
3. **Energy performance indicators**
4. **Process performance indicators**
5. **Environmental performance indicators**

In each class two or more indicators were defined to describe in the best way the different aspect involved in the line production operation condition of the permanent magnet heater.

Class n.1 – Indicators of process technical quality

- **Temperature profile of the billet after the heating process.** At the end of the heating process, the billet was extracted from the HEH heater and the temperature profile was acquired by a system of n.10 thermocouples K type. The target of the KPI is defined as the difference between the measured values and the temperature profile required by Pandolfo. This difference has to be comprised between **± 5°C**.

- **Extrusion speed measured during the process**. During the extrusion process the speed is acquired by the press system, and the value of speed is compared with historical value acquired doing the same final profile when there was the traditional AC induction heater. The target of KPI is defined as the difference between the new and the old extrusion speed. This value has to be comprised between **± 10%** of old speed value.

- **Aluminum extruded outlet temperature of the steel die**. The temperature of extruded profile after the steel die must be as uniform as possible; its value is measured by the press system during the process. The target of KPI is defined as the variation of profile temperature that has to be **less than 15°C** during the extrusion.

Class n.2 – Indicators of extruded quality

- **Maintaining of correct hardness of extruded profile**. Several samples of extruded profile are taken statistically after the extrusion end aging process and their hardness is verified.

  The target of KPI is the percentage of **scrap profile** that has to be **less than 0.2%.**

- **Surface and section quality of extruded.** Some samples of extruded profile are taken statistically at the exit of die and their surface and section are verified.

  The target of KPI is the percentage of **scrap profile** that has to be **less than 0.5%.**

Class n.3 – Energy performance indicators

- **Input power [kW].** The maximum peak of electric power absorbed by the HEH for each billet heated is measured by a power meter positioned on the supply line of heater. The target of KPI is the peak of power has to be less than the maximum power installed in the prototype 475 [kW].

- **Energy consumption [kWh/ton].** The energy consumption for the heating of every billet processed is measured by time integration of absorbed power. This value is divided by the weight of billet and reported in kWh/ton of Aluminium processed. The target of KPI is that the **energy consumed has to be less than** the energy consumed when there was the traditional AC induction heater [**19.15 kWh/ton**].

- **Energy efficiency [%].** The ratio between the thermal energy of the billet (proportional to the thermal gradient) and the electric energy absorbed by the prototype is calculated for every billet heated. The target of KPI is that the **efficiency has to be higher than 77%** theoretical value estimated during the design phase.

Class n.4 – Process Performance Indicators

- **Hourly productivity rate [ton/h].** The average productivity in term of tons per hour was calculated in the five month of on line commissioning test, this value includes all the billet processed. The target of KPI is the **average productivity has to be higher than 1.9 [ton/h]** value of previous year (2016). This indicator is important because is necessary for the calculation of next class of indictor.

Class n.5 – Environmental Performance Indicators

- **Carbon footprint (kg CO_2 eq emissions).** The value of monthly **saving of CO_2 emissions** is calculated respect the energy saving due to the new HEH permanent magnet heater versus the traditional AC induction heater. The target of KPI **has to be higher than the 6800 kg CO_2 eq. per month**, value estimated during the design of prototype.

- **Acidification potential (kg of SO_2 eq emissions)**. The value of monthly **saving of SO_2 emissions** is calculated respect the energy saving due to the new HEH permanent magnet heater versus the traditional AC induction heater. The target of KPI **has to be higher than the 30 kg CO2 eq. per month**, value estimated during the design of prototype.

KPI Results

	KEI PERFORMANCE INDICATOR [KPI]	TARGET	2017 May	June	July	August	Sept.
1	**INDICATORS OF PROCESS TECHNICAL QUALITY**						
	Temperature profile of the billet after heating process	± 5°C	OK	OK	OK	OK	OK
	Extrusion speed measured during the process	± 10%	OK	OK	OK	OK	OK
	Aluminum extruded outlet temperature of the steel die	< 15°C	OK	OK	OK	OK	OK
2	**INDICATORS OF EXTRUDED QUALITY**						
	Maintaining of correct hardness of extruded profile	< 0,2%	0,171%	0,083%	0,168%	0,030%	0,067%
	Surface and section quality of extruded	< 0,5%	0,448%	0,311%	0,205%	0,348%	0,026%
3	**ENERGY PERFORMANCE INDICATORS**						
	Input power [kW]	< 475	OK	OK	OK	OK	OK
	Energy consumption [kWh/t]	< 19,15	12,22	12,26	12,14	12,33	12,10
	Energy efficiency	> 77%	81,8%	81,5%	82,3%	81,1%	82.6%
4	**PROCESS PERFORMANCE INDICATORS**						
	Hourly productivity rate [t/h]	> 1,9	2,220	2,230	2,316	2,378	2,462
5	**ENVIRONMENTAL PERFORMANCE INDICATORS**						
	Carbon footprint [monthly kg eq of CO2 emission saving]	> 6800	7328	7073	6984	4428	8077
	Acidification potential [monthly kg eq of SO2 emission saving]	> 30	33,80	32,62	32,21	20,42	37,26

Analysis of consumption

HEH permanent magnet heater **doesn't influence the process quality and the extrusion performance** compared with traditional AC induction heater, but **it reduces the energy consumption, generating a saving of cost and a reduction of emission** respect the traditional coil Induction AC heater.

	Values related to conventional process before installation of HEH (conventional AC induction heater)	Values estimated related to installation of new HEH heating system (permanent magnet heater)	Real Values related to HEH process measured in the processing line extrapolated to higher production
CONSUMPTION	**VALUE**	**VALUE**	**VALUE**
Annual electricity consumption for induction heater / HEH	212.000 kWh	158.000 kWh	100.000 kWh
Total electricity consumption	**19,15 kWh/t**	**12,39 kWh/t**	**12,21 kWh/t**

Main advantages of HEH heater system

- **Low consumption** compared to traditional induction coil heating system
- **Limited** overall dimensions
- **High flexibility** of positioning in existing plants (also after gas pre-heating)
- **Limited** time for installation and start up
- **Simple** technological concept
- **Low maintenance** operations and costs
- Repeatability of results either in **isothermal** and **taper** heating cycle
- **No** water cooling system
- **No** hydraulic system
- **No** power transformer unit
- **No** converter unit
- **No** capacitors bank

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LCA analysis methodology

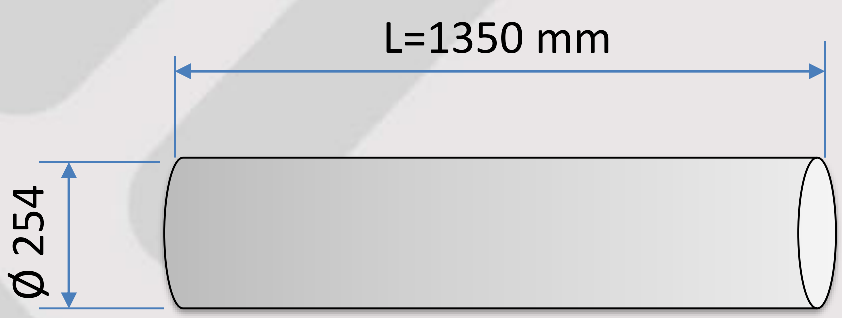
Conventional Technology:

Natural Gas heater +
Conventional AC induction heater

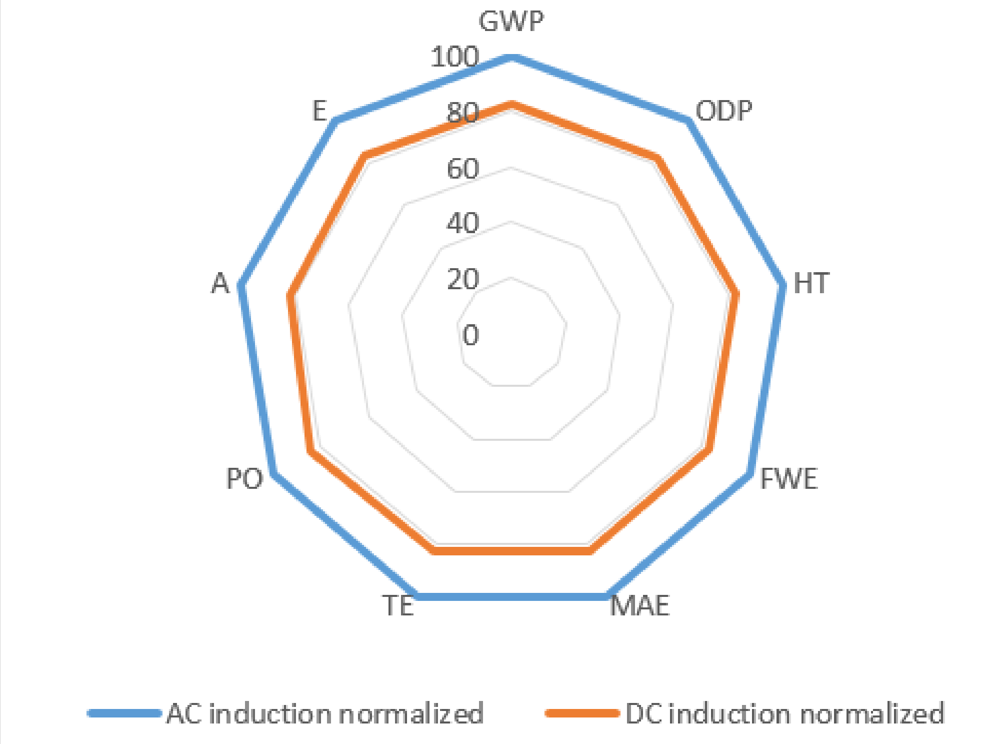
HEH Technology:

Natural Gas heater +
HEH DC induction heater

Heated Billet dimensions:



LCA analysis results



All environmental impacts indicators were reduced (near 20% less) with the HEH DC induction heater comparing to conventional AC induction heater.

This is mainly due to the electricity savings related to HEH heater.

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Offer in progress

Country: **India**

Customer Process Requirements:

- Billet dimension: **Ø6”** [152,4 mm] – L= 800 mm
- Billet inlet temperature: 20°C
- Billet outlet temperature: 550°C
- Nominal production rate: **25 billet/h** [ΔT = 530°C **Full heating**]

HEH Solution:

- Number of heating zone: **3**
- Nominal power rate for each single zone: **95 kW**
- Total nominal power rate: 285 kW
- Energy consumption: **184 kWh/t**
  [Isothermal heating – T in = 20°C – T out = 550°C]

Offer in progress

Country: **UAE**

Customer Process Requirements:

- Billet dimension: **Ø8”** [203 mm] – L= 1200 mm
- Billet inlet temperature: 20°C
- Billet outlet temperature: 530°C
- Nominal production rate: **12 billet/h** [ΔT = 510°C **Full heating**]

HEH Solution:

- Number of heating zone: **4**
- Nominal power rate for each single zone: **95 kW**
- Total nominal power rate: 380 kW
- Energy consumption: **177 kWh/t**
  [Isothermal heating – T in = 20°C – T out = 530°C]

Offer in progress

Country: **Korea**

Customer Process Requirements:

- Billet dimension: **Ø10”** [254 mm] – L= 1500 mm
- Billet inlet temperature: 400°C
- Billet outlet temperature: 500°C
- Nominal production rate: **35 billet/h** [ΔT = 100°C **Taper heating**]

HEH Solution:

- Number of heating zone: **4**
- Nominal power rate for each single zone: **115 kW**
- Total nominal power rate: 460 kW
- Energy consumption: **30 kWh/t**
  [Isothermal heating – T in = 400°C – T out = 500°C]

Offer in progress

Country: **Turkey**

Customer Process Requirements:

- Billet dimension: **Ø10”** [254 mm] – L= 1000 mm
- Billet inlet temperature: 380°C
- Billet outlet temperature: 480°C
- Nominal production rate: **35 billet/h** [ΔT = 100°C **Taper heating**]

HEH Solution:

- Number of heating zone: **3**
- Nominal power rate for each single zone: **95 kW**
- Total nominal power rate: 285 kW
- Energy consumption: **25 kWh/t**
  [Isothermal heating – T in = 380°C – T out = 480°C]

Offer in progress

Country: **Portugal**

Customer Process Requirements:

- Billet dimension: **Ø12”** [305 mm] – L= 1500 mm
- Billet inlet temperature: 350°C
- Billet outlet temperature: 480°C
- Nominal production rate: **24 billet/h** [ΔT = 130°C **Taper heating**]

HEH Solution:

- Number of heating zone: **4**
- Nominal power rate for each single zone: **115 kW**
- Total nominal power rate: 460 kW
- Energy consumption: **32 kWh/t**
  [Isothermal heating – T in = 350°C – T out = 480°C]

Summarizing, HEH offers a number of INNOVATION over existing technologies including from environmental perspective:

- Excellent heating rates and high energy conversion efficiency **(up to 80-85%)**;
- Higher efficiency (about 30%) and **overall energy saving of 50%** compared to conventional gas furnace equipped with AC induction heaters for “taper”;
- Higher energy efficiency means also **reduced CO2 emissions of about 50% and also saving of air pollutants** if the HEH technology completely replaces gas burners;
  higher flexibility EFFICIENT AND RELIABLE control of temperature distribution, depending upon the energy cost HEH will enable the manufacturer to **reduce investments, save processing time and energy and hence cut production costs**;
- No cooling water circuit required.

The system is specially interesting in those extrusion process where the «taper» is required, for replacing existing induction systems or when the existing gas heating systems are close to their capacity limits: in this case the gas pre-heating and the HEH final taper is a winning choice.

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