THE PROPERZI METHOD FOR PRODUCING PRIMARY AND SECONDARY ALUMINIUM INGOTS

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Abstract
In the year 1992 Properzi presented on the market a new ingot casting line based on the continuous casting wheel and belt technology.
The ingots produced at the rate of 15 t/h -18 t/h and being solidified in a closed and continuous mould, are characterized by fine and homogeneous metallurgical structure, absence of dross and oxide, compact shape and repeatable dimensions. This equipment and technology have found his best application in the production of light ingots (8-10 kg).
During the year 2003 Properzi has designed a new ingot casting machine called Track & Belt where the casting wheel has been replaced by a plurality of copper blocks.
With this new design it is possible to produce a wider range of alloys that eventually was not possible to accomplish with the previous Wheel and Belt Caster.
With the Track & Belt technology the de-moulding and off size rejection problems of the traditional systems have been overcome to.
This paper illustrates the target design of the Properzi Track & Belt Ingot Casting Lines and the analysis of the results gathered by the users of this technology.

1. The Background
The vast majority of data available has reported that the global production of primary aluminium in 2011 was approximately 43.2 million tons. [Metalworld - January 2012]. Either it comes from primary or from scrap reclamation the liquid aluminium is always transformed into semis (rod, slabs and billets) and re-melt forms (ingots saws and T-Bars). The rod for electrical application is always produced starting from primary aluminium due to the purity requirement necessary for having an acceptable electrical conductivity or, other way around, a lower resistivity.
The subject of this Paper is the Properzi Ingot Casting Machine, called Track & Belt, designed for producing ingots in different sizes and weights starting either from pure aluminium or from secondary aluminium coming from scrap reclamation.
The presence of the Properzi Company in the non-ferrous industry was already consolidated through 40 years of experience when Properzi designed his first ingot casting line, based on the continuous casting method with wheel and belt. This happened at the beginning of the 1990’s. At that time, China was not within the WTO agreement and Europe was achieving a new equilibrium.
with the unification of West and East Germany, whereas, in the Middle East, the invasion of Kuwait created long term consequences.

Then, Raffmetal (the largest secondary aluminium producer in Europe located in northern Italy near the marvelous Garda Lake) was looking for a new system to replace one of their existing conventional open top ingot casting machines and approached Continuus-Properzi. Raffmetal intuited that the massive globalization was just around the corner and started looking for innovative technology able to guarantee the production of ingots characterized by:

a) compact shape and repeatable dimensions and weight
b) easy and compact stacking
c) solidification such as avoid any manual skimming

All the above requirements were and are always inherent to the continuous casting method with casting wheel and belt. Our conceptual design was to manufacture a casting machine able to cast a continuous cast bar with a cross sectional area larger than 4,400 mm² and a sturdy, heavy duty rotary shear with special knives geometry able to cut the cast bar into pieces of repeatable dimensions. Basically, we had only to study how to cut the cast bar into consistent pieces of repeatable length and a nice looking appearance.

Photo nr. 1 shows part of the system. As we can see, the uninterrupted cast bar, having trapezoidal shape, passes through the rolls of the bar straightener before being cut by the rotary shear into ingots of 720 mm length with a tolerance of +/-0.5%. The ingots are then processed by the downstream equipment for the operation of stacking and strapping.

After some years, Raffmetal decided to buy a second Properzi ingot casting machine and then a third one, thereby totally abandoning the old open top casting system.

Photo nr. 2 shows a typical bundle of Properzi ingots fabricated by Raffmetal and strapped with two straps only.
At the end of the 1990’s, SACAL, located near Turin in the north western part of Italy and producing a very wide range of alloys ingots, was among the largest producers of ingots in Italy. They followed the positive experience and market success of Raffmetal and decided to install two Properzi ingot casting machines capable of producing up to 1,500 ingots per operating hour. While Raffmetal decided to produce 8.5 kg ingots, Sacal preferred to consider ingots having a weight of 10 kg.

2. International Acceptance

Everybody remembers that during the last days of 1999 there was a very generalized fear of the so called “millennium bug”. Properzi approached the new millennium with the target of serving primary smelters with its fantastic ingot casting technology. The opportunity materialized soon. In fact, sometime during 2002 ALBA (Aluminium Bahrain) announced the construction of a new pot line, “Line 5” (400,000 t/y), and in the UAE Dubal (Dubai Aluminium Smelter) announced the “Kestrel Project” covering the upgrading of the smelter for about 150,000 t/y of liquid aluminium.

This sector of industry likes very much the innovation but there is a little contradiction in the meaning of innovative and innovation. In fact, the primary smelters usually look for “the latest state-of-the-art equipment but well proven”. Although Properzi had almost 60 years’ experience in the equipment for manufacturing rod, in the sector of equipment for producing ingots we were relatively young with specific experience of only 10 years, but our technology offered a very rewarding, winning factor, intrinsic with the solidification of the liquid metal into a continuous closed mould: skimming is not required.

On the contrary, we have seen that one of the most annoying problems of the traditional open top system is the necessity of skimming the top side of the ingots to remove foam and heavy oxides. It has been calculated that even with the use of a robotized skimming station it is not possible to remove less than 0.3% in weight from each ingot. This seems like a little number, but when this “little number” is calculated over a production of 100,000 t/y we can see that, at least, 300 t/y of liquid metal is lost and needs further treatment to be partially recovered. At a very minimum LME price of 2,000 USD/t the loss of production due to the skimming operation equates to 660,000 USD/y. It is a big number!

In March 2003 Dubal finalized with Properzi a contract covering one complete ingot casting line – from casting machine down to the packaging station – sized for producing up to 2,000 ingots per hour of 99.7% Aluminium or 1,500 ingots per operating hour of various alloys. The casting machine had a casting wheel diameter of 4.2 m and the cross sectional area of the cast bar was 5,500 mm².
3. The New Track & Belt System

Mr. Giulio Properzi – son of the company’s founder, Mr. Ilario Properzi – has always believed that any good idea can be improved using imagination, intuition and the application of a critical review of concepts and equipment. It is important indeed to refrain from celebrating the present until it becomes the past.

Mr. Properzi considered that the ingots produced with continuous casting method gave tremendous advantages to the ingots producers and ingots users but he thought that the ingot casting machine could be more simple, more user-friendly and with higher production output. So back to the drawing board; he made the following considerations.

The liquid aluminium solidified in the circular copper ring needs a robust bar straightener before being cut. The bigger the cross sectional area of the cast bar, the higher is the force required to straighten the cast bar, and consequently, the dimension of the bar straightener. For some hard alloys the “game” results almost impossible. We have not mentioned that accommodating a casting wheel having a diameter of 4.2m in the casting pit required a very deep foundation pit. So, what to do to keep the concept of the solidification in the continuous closed mould but escaping from the casting wheel and belt? The photo nr. 4, showing the TRACK & BELT PROPERZI caster, is self-explicative.
The circular copper ring mould has been replaced by a plurality of blocks made by a copper alloy and arranged in succession on a chain. As a consequence, the closed continuous mould is composed on the upper side by the continuous steel belt and on the other three sides by the three sides of a plurality of blocks as we have said. The length of the mould is determined by the distance between the clamping wheel (1) and the clamping wheel (2). The tracking wheels (A) and (B) move the caterpillar, like the chain of a bicycle. The steel belt is pushed against the active chain of blocks, to form the top part of the closed continuous mould, by a series of rolls operated by pneumatic pistons. The steel belt is powered by wheel (2) in a way that in any point of the closed mould the speed of the caterpillar and the speed of the steel belt are exactly the same. It is needless to say that the speed of the caterpillar is equal to the casting speed. It is quite evident that we can have a very long mould, i.e. very high production rate, without having negative effect on the foundation and installation costs. The photo represents the 5th industrial Track & Belt Casting machine that has been delivered to Raffineria Metalli Capra in Italy, but there is a long story even before the 1st Track & Belt caster that is presently running at Carlo Vedani Metalli (a very well known European producer of secondary aluminium with over 100 years of experience located in northern Italy) and displayed in Photo nr. 5 together with the inventor Giulio Properzi.

First, our engineering team designed a small pilot unit (Photo nr. 6). This unit was designed and manufactured during year 2002/2003. The machine had the same configuration of the industrial machine shown in Photo nr. 4 but with dimensions approximately 20 times smaller (see Photo nr. 6). The cross sectional area of each segment mould was about 450 mm² and the production rate was in the range of 0.8 t/h. The line was fed with a pilot combined melting/holding furnace, tiltable type, having a basin capacity of approximately 6 tons.
At the beginning our tests were focused on the kinematics of the various segments, while rotating and while translating in the rectilinear part of the machine. Specifically, a point of concern was the eventual possibility of having some leakage of metal among the plurality of active segments (those closed at the top by the steel belt). This risk has been avoided by having all the active copper blocks traveling in a constant compression status along the rectilinear active stroke of the machine, through the action of one bidirectional variable speed motor. After that, we saw that the mechanical attributes and kinematics of the continuous caterpillar mould were moving smoothly and with adequate sealing among the various copper blocks; we started the casting trials, casting EC grade 1350 aluminium, considering to cut the cast bar so produced with a manual hydraulic shear. The various trials proved that the intuition of this new configuration of the casting machine was correct. Some trials on the small machine were witnessed by Vedani Carlo Metalli who decided, as we have said, to buy the first Properzi Track & Belt Caster. The line started the industrial production of 10 kg ingots during the year 2006.

Also Raffmetal decided to switch from the previous Properzi Wheel and Belt caster to the new technology of Track & Belt. Presently, Raffmetal has three Track & Belt casters each producing up to 2,000 ingots per operating hour (ingots weight: 8.5 kg).

Raffineria Metalli Capra, with their Ingot Casting line Track & Belt produces up to 2,000 ingots per operating hour in the two different sizes: Format A: 10 kg; Format B: 8.5 kg.

4. The value of innovation

It could seem a banal statement, but for transforming liquid metal into ingot shape, it is necessary to foresee an appropriate mold where, liquid metal, protected as much as possible from the atmosphere, can change its status from liquid to solid, through the action of a cooling means.

Solidification time is directly proportional to the heat transfer between the mold and cooling means, while heat transfer is in general ruled by the following formula, better known as Fourier’s postulate.

\[
Q = \int_0^T - \lambda \cdot \theta \cdot \Delta T \cdot K \cdot dt
\]

Whereas:
- \( Q \) is the heat transferred
- \( \lambda \) is a coefficient that keeps into consideration the geometry and physical characteristics of the mold (in our case)
- \( \theta \) is the surface area of the mold involved in heat transfer
- \( \Delta T \) is the temperature difference between the mold and cooling means
- \( K \) is an appropriate coefficient for homogenizing the dimensions of the units involved in the formula
- \( dt \) is the time involved in heat transfer
Looking at this equation, it is quite evident that the efforts made by technologists during the past years have been addressed in increasing the efficiency of heat transfer while reducing the time required for the solidification. The photo nr. 7 displays a typical ingot cast into an open top conveyor. Geometry and weight have varied in the past, this shape of ingot, with a design that varies just in small details from producer to producer, has piqued the worldwide preference and has become the most common ingot on the market, even though it is not the only one.

To understand the reasons of this shape, we should go back to the pioneer systems used by the industry to produce ingots, and also consider the level of automation and the technology available at the end of the 1950’s. At that time, only the open top chain conveyors were available and, in this equipment, the production output is ruled by the following equation:

\[ P = K \frac{W \times L}{I_s \times t_s} \]

Where:
- \( P \) is the hourly output of the line
- \( K \) is an appropriate coefficient to homogenize the various units
- \( W \) is the ingot mass
- \( L \) is the line length
- \( I_s \) is the spacing between moulds
- \( t_s \) is the solidification time

From this equation it appears that, once the length of the chain conveyor has been determined (i.e. the equipment cost), somehow, the more the weight of the ingot the higher is the output…. and, in the sector or primary ingots the weight of 50 lb (22.7 kg) has been consolidated.

However, even the most well-established traditions must be overcome when new process techniques are developed to offer improved quality with lower or equal costs (equipment and transformation). The production rate of the Track and Belt exceeds 2,000 plus ingots per operating hour. The ingots produced with Properzi Track & Belt are characterized by:
- Constant weight
- Repetable geometry
- Absence of dross in the top surface
- Skimming is not required
- No rejection for off size ingots

Innovation is an effort that is meant to give to the industry not only higher profits and lower transformation costs, not only better and repeatable quality but, above all, better working conditions for the human being and increased safety.

5. References
1. “Metalworld- January 2012