Pechiney has been dedicated to developing twin roll casting of aluminum technology and products for more than 40 years. Lately a new generation of machines, the Jumbo 3CM®, has emerged to complete the range of equipment available to produce hot rerolls on an economical basis. The Jumbo 3CM® includes the latest technological developments that Pechiney has designed in order to:
- Reduce casting gauge;
- Increase productivity and casting width;
- Increase quality of existing products and improve the consistency of the cast quality;
- Develop new products from continuous cast sheet.

The following sections summarize these developments and shed light on Pechiney’s commitment to being a leader in continuous casting technology for aluminum flat rolled products.

These developments have made possible the casting of alloys for more demanding products such as can stock, thin gauge foil, litho sheet and automotive sheet.

During twin roll casting brief history, emphasis was placed on achieving the same strip surface quality and geometry as those of a strip coming out of a hot mill, be it after a belt- or block-caster or from a conventional hot mill.

That is achieved for alloys with low element content typically from 1xxx series (e.g. operation at Norandal “Quantum Leap” plant in Huntington, TN). For high element content alloys, casting parameters have to be adjusted in order to prevent formation of detrimental segregations. Still robust windows of operation can be found for 3xxx and 5xxx series alloys (e.g. operation at Hydro plant in Karmøy, Norway, which has a longstanding experience in casting 3003 and 5052 alloys).

A key difference between twin roll casting and DC casting is the solidification rate of the metal: while in DC casting it is limited to 1 to 50°C/s, it reaches 1000°C on Jumbo 3CM®. This gives very fine structures (DAS ~ 5.0 µm) with smaller finely distributed intermetallics. Also the extent of elements in solid solution is increased, opening the way for example to alloys with higher iron content. Final properties of products can benefit from that too. Another advantage is the use of cheaper scrap. In any case, good metal treatment is required in order to obtain consistent quality and to address demanding applications such as thin gauge foil. Thus a typical casting line aiming at producing this kind of products comprises a degassing unit and a filtration unit.

The development of strip casting technology by Pechiney has been carried out on 2 pilot lines in the past 10 years:

- A Jumbo 3C® 620 pilot caster located in the Pechiney Research Center in Voreppe, France;
- A Jumbo 3CM® 1150 industrial pilot line located in the Pechiney Rhenalu Neuf-Brisach plant, France.
While the pilot in Voreppe has a limited capacity (it is fed by one 3-ton furnace and casting width is 400-mm), the Jumbo 3CM pilot line in Neuf-Brisach is a full-scale caster. It has been in operation for five years to serve different development programs. Lately, a small part of its time has also been allocated to production. Teams of engineers, technicians and skilled operators are working on these installations on a daily basis benefiting both from the environment of the Research Center (in Voreppe) and that of one of the best performing plants in the world for flat rolled products.

The technology itself has evolved to offer cheaper though still more reliable equipment to customers. As far as product quality is concerned, the keys are in the control of the heat exchange between aluminum and the rolls. Several issues have to be addressed:
- Metal feeding;
- Roll cooling;
- Roll lubrication and coating control.

They will now be discussed in further details.

**Metal feeding**

The prerequisite to a good metal feeding is to have a liquid metal with the proper gas and inclusion contents. This is achieved by having the metal flow through a degassing unit and filtration unit, preferably a deep bed filter. The life and filtration efficiencies of such type of filters are better than those of ceramic foam filters. Metal feeding is critical in the sense that the velocity field and temperature distribution at the outlet of the tip that brings the metal in the roll bite affect the shape of the solidification front. For example, a hot stream of metal (by 10 to 15°C) in one area across the width will lead to a deformation of the solidification front forward towards the exit of the rolls. At best, this translates into a gauge reduction in this particular area of the width. At worst if the caster operator doesn’t correct the defect, it can lead to a bleed-out. Till the mid-90’s it was considered that a limit of productivity was the occurrence of bleed-out when reaching a certain speed (ref. (1)). This limit still exists now but Pechiney has designed a metal feeding system to enables the operator to have a better control of the metal flow in the tundish prior to entering the tip (patented system (2)). While a defect in the flow can lead to a bad geometry, conversely, the operator can change the flow within the tundish to alter the cross profile of the strip. This actuator on the cross profile of the strip could only be discovered with the installation of a tool to measure continuously the profile of the strip, namely a traveling X-ray gauge. With it the operator has an instantaneous answer of the process to his action.

Beside the liquid metal flow pattern in the tundish, an important part of the metal feeding system is the tip. For thin strip casting, a new tip had to be developed. As the gauge is reduced, the space between the rolls for a given setback is reduced. Either there is less space for the metal to flow through or the lips of the tip have to be smaller.

To complete the device, the tundish together with the tip can be precisely adjusted with respect to the rolls thanks to the new tip support table. This table allows for motion in every direction: back and forth to adjust the setback of the tip on each side respectively. It can move up and down to maintain a proper gap between the tip lips and the rolls as a contact between the tip and the rolls can be very detrimental to the integrity of the strip.

The above features concerned the control of metal temperature and velocity along the metal feeding device. The solidification is also determined by a third important parameter: the metallostatic pressure of the metal at the outlet of the tip. See figure 2.

![Figure 2 - PAE Level control design](image)

Figure 2 - PAE Level control design

This parameter is called metal level or metal head. It determines the intensity of the heat transfer at the onset of solidification. Thus it is a critical parameter as it influences both solidification and strip geometry. The metal head control device, i.e. flow control device, is achieved by a horizontal actuator piloted by a PID controller fed by the head measurement from a capacitance sensor located downstream. Performance observed at customers’ locations is better than ±0.3-mm variation of the metal head.

**Roll cooling**  (patented cooling system (3))

For thin gauge casting, the separating force on the rolls is higher so as to obtain a satisfactory microstructure on the as-cast material. To achieve that, the core+shell assembly had to be revised. An original 6-hole configuration is now proposed based upon numerical modeling taking into account both the thermal and mechanical aspect of the case. The objective was to minimize the roll thermal deformation due to non-uniform cooling and the out-of-round created by the mechanical deformation.
Roll lubrication and coating control
The roll/metal interface plays a key role in the quality of the as-cast strip. The main parameters that govern the roll/metal interface are:
- Composition and consistency of the oxide layer at the roll/strip interface.
- Amount of release agent or lubricant deposited on the shells.
- How the lubricant is deposited on the shells.
Following the experience gained on the pilot caster at Pechiney Research Center, a new spraying system was designed. The objective was to have more graphite on the rolls and less in the atmosphere and especially on the strip and to have a more uniform deposit on the shells.

This tool has proven very useful to reduce and ultimately eliminate the intensity of surface segregations when casting thin strip. Figure 4.

In summary, these developments have allowed the casting of alloys both at thinner gauge and higher productivity, as never achieved in the past. Some of these developments are listed in the next part.

Product developments

Foilstock
A large part of our research programs is devoted to determining thin casting conditions and downstream processing schedules for alloys 1xxx and 8xxx for foil, fin and other applications (ref. (4,5)). Alloys 1235 and 1145, market references for the Tetrapak application at 6.35 µm, were chosen to determine the casting conditions and the processing schedules for thin gauge 3CM metal for foil end uses.

To produce strips that can be successfully rolled down to a final gauge between 6 and 8 µm, the key conditions are:
- **Optimize the casting profile** on the JUMBO 3CM® caster in order to ensure good strip flatness throughout the processing steps. The target transverse profile is a crown of 0.4 to 1 % maximum and the longitudinal thickness variations must not exceed 1 to 1.5%.
- **Get a sound metallurgical structure during casting.** The major issues are to eliminate both centerline and surface segregation, as well as to obtain fine and uniform grain size distribution across the width.
- **Reduce the oxide level and surface roughness of the as-cast strip.** Under normal conditions, the oxide level on thin gauge as-cast strip is about 50% more than for standard gauge strip casting and several times the oxide level obtained on DC material. Trials performed with a new release agent and coating control system have permitted to significantly reduce the oxide level.
- **Optimize the position of the heat treatment** or treatments within the processing schedule and their conditions. A compromise is to be reached that gives the metal a fine granular structure, good ductility, good mat side surface aspect and low pinhole content.

Aluminum foils between 6 and 8 µm were produced at the issue of the campaign of trials. The metal porosity was examined by image analysis. The totality of the pinholes greater than 2 µm can be counted using a method of measurement developed by the Voreppe Research Center. However, the size of the pinholes remains extremely low, generally less than 20 µm. Pinholes of this magnitude are disregarded in the measurements covered by European standards (Standard EN546-4).

The lower oxide level in relation to pinholes is under investigation. With these conditions, we expect the pinhole number to be below 300 per square meter.
Some of Pechiney customers, operating JUMBO 3CM® casters have already implemented in their daily production the results achieved at Neuf-Brisach. In particular, CBA (Brazil) is producing on a daily basis foil from 3CM rerolls for several months, at gauges between 2.5 and 3.5 mm.

For lighter gauges (typically 2mm) casting technology has proved suitable and processing trials are ongoing to assess the effect of the reduced thickness on the metallurgical quality of the final product.

Thin gauge as-cast coils in 8xxxx series alloy for high strength foils are under development. Finstock made from 1xxx and 8xxx alloys are under investigation so as to defining the best compromise between the mechanical performance and economical processing route.

Lithographic and high bright sheet

Pechiney started the development of strip-cast 1xxx alloys for lithographic and high bright applications in 1997. The developed casting process and downstream processing were implemented for lithographic electrograined sheet early 1998 at Choil, South Korea. At this time, the casting gauge was between 3 and 6 mm.

The key points for these developments were:
- A new metal feeding system.
- The roll-strip interface control in order to achieve a uniform as-cast surface quality.

Due to the high solidification rate, a large amount of iron is trapped in solid solution and a high reflectivity (85%) of the strip at the final gauge is obtained.

Near net shape applications

These developments started early 1997 and this technology is already implemented in some of Pechiney customers’ plants.

The range of casting thickness is dictated by the final end uses and is situated between 2 and 4 mm. Casting conditions are of course specific to each composition.

An extremely interesting and surprising compromise between anisotropy, ductility and tensile strength (patent pending (6)) was reached with as-cast 3CM strips of Al/Fe/Mn/Si alloys, once casting conditions were optimized. Mechanical properties are determined on a first degree by casting conditions and not by metal composition. Ranges of properties that are not accessible via DC processing route are opened up using the 3CM process.

Can body stock (covered by patent (7))

For canstock applications, the difference in properties and in metallurgical structure between 3CM metal and metal produced by the classical DC process is such that the alloys generally used with traditional casting (such as 3104 for can bodies) were not suitable. Thus the objective of the trials was to define the appropriate composition for each application combined with the appropriate casting conditions. Trials carried out at the Research Center at Voreppe and on the pilot 3CM caster at Neuf-Brisach have enabled us to explore contents ranging between 0.9 and 2.2% for Manganese, between 1 and 3% for Magnesium, between 0 and 0.5% for copper and 0 and 0.5% for Chrome.

Each composition was then tested during semi-industrial trials:
- Casting on the JUMBO 3CM® pilot caster at Neuf-Brisach. The range of thickness explored was quite wide, between 2.5 and 4 mm.
- Industrial processing of the coils on the industrial rolling lines for canstock at Neuf-Brisach.
- Fabrication of finished products on pilot lines at Pechiney Research Center and at canmakers’ facilities.

These trials have lead to the definition of a triple combination of casting conditions / composition / processing schedule, resulting in the successful fabrication of over hundreds of thousands of can bodies with no tear-off or galling. Validation on an industrial scale is on going (ref. (8)).

Automotive sheet

On the same lines as kitchenware applications (near net shape applications from as-cast material), development is ongoing for alloys and casting conditions for the production of structural parts. The compromise between tensile strength and elongation for as-cast 3CM 5xxx alloys allows us to envisage an ultra-simple processing schedule.

As for kitchenware applications, the thickness range is dictated by the final end uses i.e. between 2.5 and 3 mm. Preliminary results are promising and reveal high potentials for 3CM thin gauge casting.

The investigation of other properties (corrosion and joining) is currently in progress.

■ Outlook

Besides the improvements in continuous casting technology and the development of new products, PECHINEY is continuing to promote the sale and marketing of both conventional (3C) and thin gauge casters (3CM).

This activity has been particularly active and successful over recent years and our customers can now benefit from all our improvements, in terms of technology and new products.

NORANDAL Huntingdon has confirmed its confidence in PECHINEY technology by ordering, last year, two new JUMBO 3CM® large width (2300 mm)
casters corresponding to the phase II of the “Quantum Leap” project. These casters, under final testing in July 2001 are dedicated to fin stock production and complete the two JUMBO 3CM® casters of phase I delivered in 2000. Large width 3CM technology also convinced CBA in Brazil to whom two JUMBO 3CM® casters will be shipped in July 2001. These casters, dedicated to thin gauge foil stock, will be added to the 6 PECHINEY casters already in operation in this plant, making CBA the largest continuous casting producer in South America. One JUMBO 3CM® caster was also installed last year in PROFILGLASS, Italy, to produce 3000 and 5000 series alloys for aluminum tubes.

The number of PECHINEY JUMBO 3CM® casters installed around the world stands now at 19 units and the trend from the major aluminum producers to consider the continuous casting route as the most economical solution for new projects will see this number increase significantly in the near future.

References

(2) "Process and device for controlling the thickness profile of a thin metal strip obtained by continuous casting between mobile molds" – PY. Menet, L. Calaque. FR 2 775 916, WO 99/00527.

(3) "Process and device for correcting the out-of-round of rolls for the continuous casting of metal strip" US patent 5642772.


(6) "Method for making aluminum alloy strips by continuous thin gauge twin-roll casting" International patent application WO 98/52707.

(7) "Process for producing a thin sheet suitable for making up constituent elements of cans” - US Patent 5616190.

(8) "Development of sheet for canstock and other applications on Pechiney Neuf-Brisach JUMBO 3CM® caster” –

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