Essential Readings in Light Metals: Cast Shop for Aluminum Production.
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CREM - A NEW CASTING PROCESS

PART II - INDUSTRIAL ASPECTS

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Industrial tests on CREM process were carried out using a specially designed casting equipment which allows to cast simultaneously from the same furnace two slabs, one by the classical D C process the other by the CREM process. The slab size was 1360 mm x 610 mm. The CREM part of the equipment was calculated to increase the forced convection in the sump.

Slabs of 3004 and 5182 were cast with this equipment in the Aluminium Pechiney casthouse of Noguères, then scalped, rolled and transformed. We particularly focused our attention on the following points : grain size, scalping thickness, edge trimming and final quality of the products.

The results prove that with respect to the classical D C casting process the new CREM process allows to cast industrial products without any grain refiner addition. The final quality of the products is better and substantial savings in scalping and edge trimming can be obtained.

INTRODUCTION

The CREM process (1) developed by Pechiney can be employed to :

Cast products

and

Refine the as-cast grain size.

It is based on techniques which are :

Electromagnetic,

whence the name.

Part I presented the scientific aspects of the process, highlighting the potential advantages, viz :

- the stirring of the molten metal induced by the low-frequency current brings about a grain refining effect sufficient to eliminate the need for AT5B, with attendant cost savings, a probable improvement in quality and, needless to say, an extension of the working life of the liquid metal filtration systems ;
- product surface condition is better than obtainable by vertical D C casting, with attendant savings on scalping and edge trimming.

A point to note is that the CREM process operates directly on the mains supply frequency (50 Hz in Europe), so that the power supply system is relatively straightforward.

The results presented in Part I are however of limited scope :

- they refer solely to billet, whereas the bulk of output relates to slab ;
- they refer to only one type of alloy (2214), accounting for only a fraction of the tonnage cast ;
- casting was carried out exclusively at the Research Centre, so that metal quality was not always representative of commercial production.

From the industrial viewpoint, therefore, prompt answers were needed to a number of questions, viz :

- how could the CREM process be adapted to slab ?
- what were the likely problems facing the industrial implementation of the process ?
- would metal quality not be adversely affected by the electromagnetic stirring of the melt induced by current supplied at industrial frequencies ?
- what advantages were to be expected in terms of grain refining, scalping and edge trimming ?

Experiments were set up with the aim of obtaining accurate answers to these questions. The conditions adopted were as follows :

- the 3004 and 5182 canstock alloys were selected because of their substantial production tonnage, in the 1360 mm x 610 mm format (approx. 24" x 54") ;
- all casting runs were carried out at Aluminium Pechiney's Noguères casthouse ;
- rolling of the slab so obtained was fully monitored and estimates made of savings at the rolling stage.

PROCEDURE

The procedure adopted consisted of casting two slabs in parallel from the contents of one and the same furnace :

- one by the conventional vertical D C process,

- the other by the CREM process.

Thus, each slab cast by the CREM process was paired with a "control" for the purposes of comparison.

This ensured that any two slabs compared had exactly the same composition and originated from liquid metal subjected to the same treatment. They were therefore identical in terms of liquid metal quality, so that any observed difference in final quality would be related directly to the differing effectiveness of the casting processes employed.

The experimental arrangement employed for this investigation consisted of a twin-strand casting station (Fig. 1), rigged for conventional vertical D C casting on the left and CREM casting on the right. The metal feed from the furnace (to be seen on the far right) was treated in an AlPur D 2000 degassing ladle. The final portion of the feed trough was divided into two channels by a refractory weir. In the channel feeding the control slab, AT5B rod was introduced sufficiently far upstream, allowing for the rate of metal flow, for it to have time to dissolve completely. In this way, only the control slab was chemically refined, the CREM-cast slab containing no AT5B refiner, and the grain size obtained could be accounted for only by the electromagnetic stirring effect.

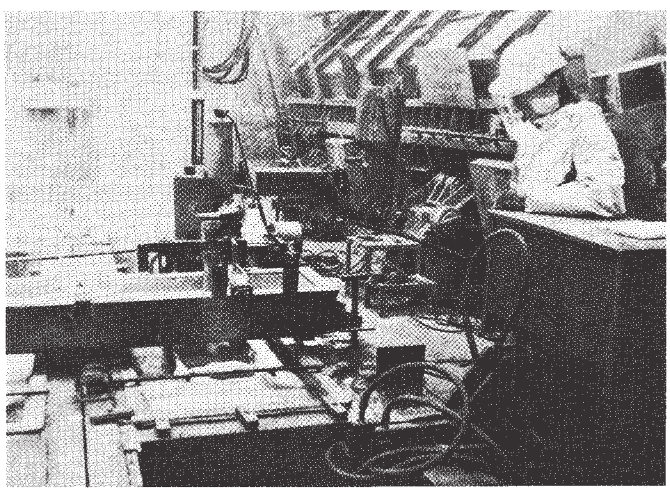

FIGURE 1

TWIN-STRAND CASTING STATION. ON THE LEFT CONVENTIONAL VERTICAL D C CASTING, ON THE RIGHT CREM CASTING

Fig. 1 also shows the system of melt level regulation employed in the Noguères casthouse, with particular reference to the sensor and the plug actuator employed to control metal flow (2).

DESIGN OF CASTING EQUIPMENT FOR THE CREM PROCESS

The studies carried out at the Research Centre on billet (see Part I) had already afforded a degree of experience in the design of CREM casting units. However, the plant and equipment employed in these trials suffered from numerous shortcomings, e.g. the use of expensive, low-strength materials, or electrical hazards. It was not therefore advisable simply to extrapolate the CREM slab casting equipment from that used for billet. Especially since it had been noted that the direct use of the mains current frequency opened up a range of possibilities as regarded the electrical installation, and hence afforded a fair degree of flexibility in casting system design.

It was therefore decided to design a CREM slab casting unit around the following requirements :

- sufficient electrical power to develop the electromagnetic effects needed to refine grain size and reduce chill zones ;

- full observance of electrical safety standards ;

- equipment to be rugged (for use in an industrial environment) and involve minimum manufacturing cost, but without detracting from electromagnetic performance ;

- but with extensive scope for adjustment of settings, since this was a prototype system.

To determine the best compromise, we simulated by computer the effect on the shape of the free surface meniscus and on the melt flow pattern of :

- the nature and geometry of the various components of the casting unit (inductor, mould and waterbox) ;

- the geometry of inductor windings and number of turns.

The simulation was based on resolution of Maxwell and Navier-Stokes equations.

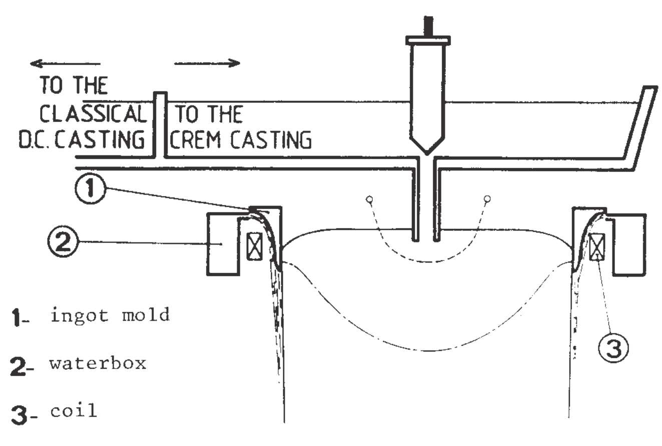

FIGURE 2

SCHEMATIC SKETCH OF THE CREM PROCESS

Finally, for the 1360 mm x 610 mm format, the inductor is supplied at very low voltage (well below the 24 V safety limit for a humid environment applicable in France). To this end, a step-down transformer is sited close to the inductor (shown on Fig. 1). Typical total power consumption is some 30 kW.

A schematic sketch for the CREM portion of the casting system is shown in Fig. 2.

SLAB CASTING TRIALS USING THE CREM PROCESS

Before attempting to quantify the results of CREM casting in terms of grain refining and evaluate product quality, the investigation concentrated on confirming the ability of the process to cast slab and on optimising operating conditions. The opportunity was also taken to measure current densities in the melt in order to check the validity of the models.

Feasibility of slab casting by the CREM process

In the light of a small number of test runs and adjustments, it was concluded that the CREM process was suitable for slab casting. Slab of good geometry and free of surface defects was obtained without major problems. Good regulation yielded an attractive surface finish characterised by a very smooth skin (see Fig. 3).

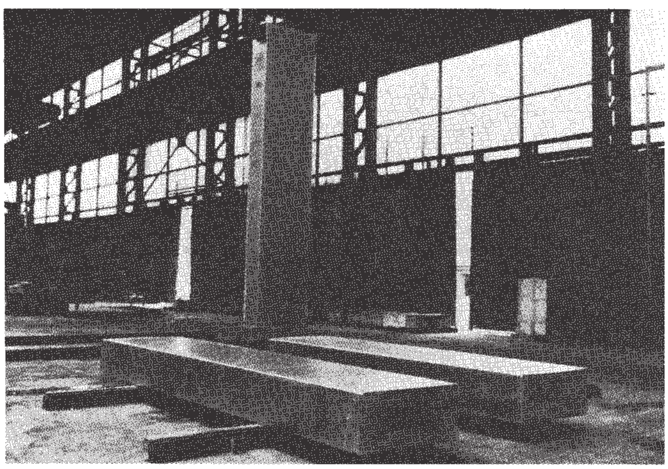

FIGURE 3

CREM SLABS

It deserves to be stressed that the CREM casting unit was installed in an existing casting pit and that only part of the tooling had to be changed to suit the process. Additionally, the flexibility afforded by the use of current at the mains frequency ensured good compatibility with the casting units already being operated at Noguères. So as not to affect output at Noguères unduly, the CREM trial runs were fitted into the production planning schedule. This was feasible in that change-over from the CREM process to conventional casting took no more than an hour, inclusive of electrical connections.

Comparison of experimental data and predictions

Advantage was taken of the initial casts to carry out current density measurements in the liquid sump in the neighbourhood of the inductor. This was done using probes similar to those described in Part I, although conditions were rather more difficult than at the Research Centre. The shape of the free surface meniscus was determined simply by displacement of an alumina rod.

Fig. 4 shows the set of results obtained at the mid-point of a major face of the slab at a total power input of 55 kW. As in the case of billet casting, it can be seen that current densities fall off exponentially with distance from the face.

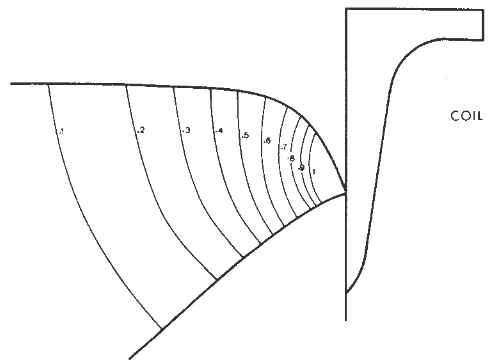

FIGURE 4

EXPERIMENTALLY MEASURED CURRENT DENSITY AND SHAPE OF THE FREE SURFACE AT THE MID-POINT OF A MAJOR FACE

Fig. 5 shows the predictions of the computer calculation for the same operating parameters.

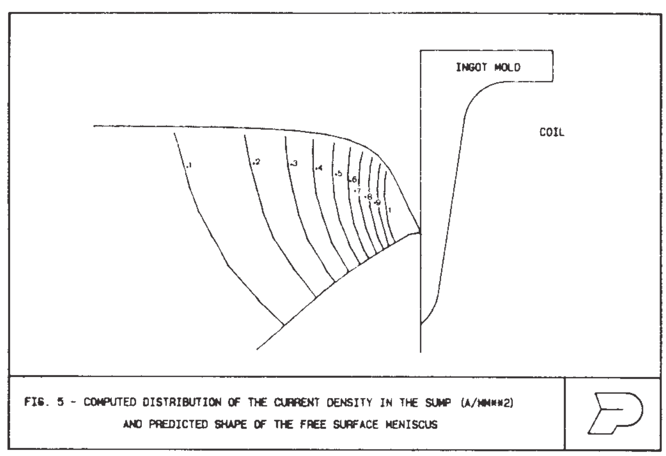

FIGURE 5

COMPUTED DISTRIBUTION OF THE CURRENT DENSITY IN THE SUMP (A/mm^2) AND PREDICTED SHAPE OF THE FREE SURFACE MENISCUS

Comparison with Fig. 4 shows good agreement between the experimental and computed data as regards both induced current densities and the height of the liquid metal dome, thus confirming the validity of the initial calculations. Additionally, the computed values for the various electrical parameters of the system (voltage, current and wattage) proved to be accurate, as evidenced by comparison with the results of continuous recordings during casting.

This means that CREM casting units for other formats operating on the 50 Hz (European) supply or 60 Hz (North American) supply can now rapidly be designed and optimised.

CASTING 3004 ALLOY

The goals of the work reported were (i) industrial casting of slab with no addition of nucleating agents and (ii) evaluation of the quality of the rolled products obtained therefrom.

Therefore, the first case examined was that of 3004, knowing that the grain refinement of this alloy would be the most difficult.

As-cast grain size

Alloy structure was first checked by macrographic examination of a slab slice. Feathery structure was found to be absent and grain size was uniform over the whole of the surface. The grain size at the mid-point of the slab was therefore taken to be representative and was measured by the mean-intercept method.

Fig. 6 illustrates the effect on grain size of power dissipation in the inductor. As for 2214 alloy cast as billet, the as-cast grain size of 3004 alloy slab was found to reduce significantly with power input. These results are in agreement with data from other physical refining tests (ultrasonic, propeller stirrer, etc.) (3, 4).

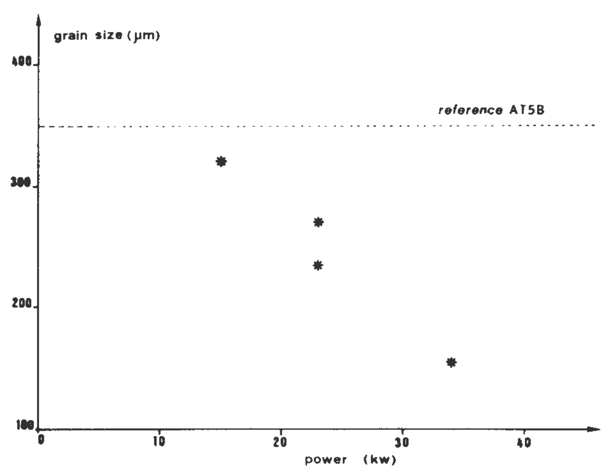

FIGURE 6

EFFECT ON THE GRAIN SIZE OF POWER CONSUMPTION IN THE INDUCTOR

The table below illustrates the variation in the respective operating costs of physical grain refining by the CREM process and chemical refining with AT5B, as required to obtain a 200-micron grain in a 3004 alloy slab of format 1360 mm x 610 mm.

TABLE 1 : COMPARISON OF THE PHYSICAL AND CHEMICAL GRAIN REFINING

Refining mode	CREM	AT5B
Consumption	4.5 kWh/t	1 Kg/t
Approximate cost*	$ 0.13/t**	$ 2.9/t

* $ 1 = FF 7
** based on average cost per kilowatt-hour in the EEC

This comparison affords an idea of the operating savings achievable with the CREM process, to consider only the grain refining step.

Scalping

The thickness of the chill zone obtained with the CREM process in the experimental runs can be estimated from Fig. 7 at some 1 to 2 mm.

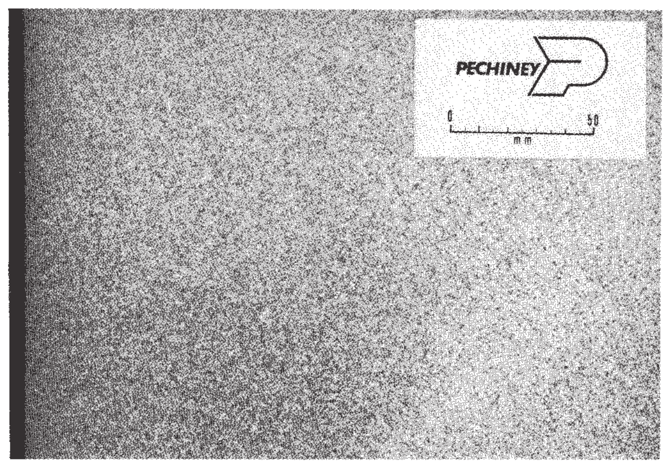

FIGURE 7

MACROGRAPHIC PICTURE OF A 3004 SLAB SLICE CAST BY THE CREM PROCESS

Superficial scalping of the slab cast by the CREM process eliminated every trace of chill zone ; this was however in no case found to be possible with the control slabs.

CREM slabs therefore required only light "cleaning" of the major faces to eliminate casting skin prior to rolling and guarantee satisfactory finished product quality.

Savings on edge trimming

3004 alloy is not over-sensitive to edge problems. However, the improvement afforded by the CREM process in the case of a product hot-rolled to a thickness of 3.5 mm is shown by Fig. 8 : the edges are distinctly better than obtained with conventional vertical D C casting. This is to be explained by the excellent surface finish of the narrow sides of the slab obtainable under well-controlled conditions by CREM casting.

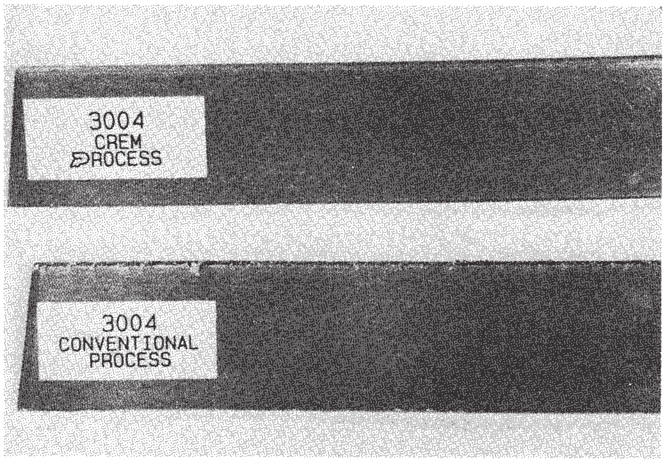

FIGURE 8

EDGES OF 3.5 mm HOT-ROLLED PLATES FROM 3004 ALLOY

Metal quality

Quantification of the quality of metal leaving the casthouse remains a difficult and controversial subject. This is why only a modest set of results can as yet be offered on the CREM process. The rating system employed is the result of an internal test method. It refers to the as-cast condition of the metal, the rated index increasing as metal quality deteriorates. Results for three casts carried out in parallel are tabulated below.

TABLE 2 : COMPARISON OF THE METAL QUALITY

Refining mode	Cast 1	Cast 2	Cast 3
CREM	13	5	0
AT5B	23	13	1

These results, which are felt to be significant, indicate that the CREM process affords an improvement in metal quality as compared to conventional vertical D C casting processes employing a grain refiner.

CASTING 5182 ALLOY

In view of the good results obtained with the CREM process on 3004 alloy, a similar comparative study was carried out on 5182. No difficulty was encountered in fine-tuning the casting of 5182 by the CREM process. Additionally, metallurgical considerations suggested that 5182 might be expected to be more effectively refined by stirring than 3004.

The results of casting 5182 will therefore be discussed in less detail than those relating to 3004.

Grain size

As expected, for the same power input and the same casting conditions, the 5182 alloy grain was found to be finer than that of 3004 : the average reduction in size was from 300 to 120 microns.

Scalping

Results concerning scalping of slab cast in 5182 by the CREM process were similar to those for 3004 : chill zones were very thin - of the order of a millimetre - and defects were completely removed by superficial scalping. The control slabs invariably required a deeper cut.

Savings on edge trimming

5182 alloy is susceptible to edge cracking and comparison of the results of the CREM process and conventional vertical D C casting, respectively, was therefore of particular interest. Fig. 9 illustrates the appreciable reduction in the length of edge cracks on strip rolled from the CREM slab, signifying a potential saving on edge trimming.

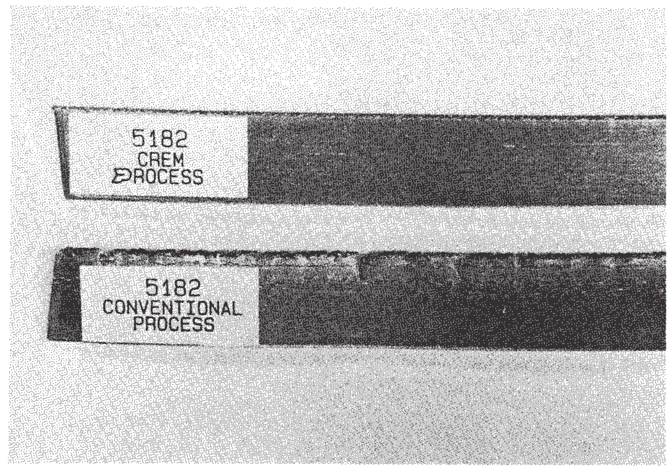

FIGURE 9

EDGES OF 3.5 mm HOT-ROLLED PLATES FROM 5182 ALLOY

CONCLUSION

The trials carried out on the plant, all of which were run at Aluminium Pechiney's Noguères casthouse, showed the CREM process using current at the standard industrial frequency to be capable :

i) of producing 3004 and 5182 alloy slab in the 1360 mm x 610 mm format (24" x 54")

ii) of yielding as-cast grain sizes in the slab so obtained of 300 to 150 microns with no addition of grain refiner.

On rolling the slab, it was found that the CREM process afforded appreciable savings on scalping and edge trimming operations.

The determinations carried out as part of the investigation also showed an improvement in the quality of metal cast by the CREM process as compared to processes employing heterogeneous refining agents.

ACKNOWLEDGMENTS

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