Light Metals 2012 *Edited by: Carlos E. Suarez*
TMS (The Minerals, Metals & Materials Society), 2012

Light Metals 2012

CAST SHOP for ALUMINUM PRODUCTION

Furnace

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AUTOMATED MEASUREMENT OF LIQUID METAL HEEL AND FULL FURNACE WEIGHT IN TILTING FURNACES

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Keywords: BatchPilot, Furnace Weighing

Abstract

The benefits of accurate measurement of furnace heel and full furnace weights are well accepted in terms of increasing % right first time batching, increasing productivity and eliminating short casts however the practical realization of a robust system has been problematic. The development of the BatchPilot system, which has overcome these difficulties, is described. To date 47 systems are in operation in 20 casthouses world wide and the most recent innovations include a fully automated weighing capability and down line integration of the output data into the customer management data network.

Introduction

Effective process control to achieve optimum efficiency in terms of cost of production, productivity, quality and yield requires accurate measurement of process parameters. In the production of aluminium semi finished shapes in the casthouse difficulties arise with the accurate measurement of the weight of molten metal in the furnace – either in the form of a heel left after completion of a cast or the amount of molten aluminium transferred into the furnace, in the case of a holding furnace where transfers are necessary from a melting furnace. Today weight is generally estimated visually and an accuracy of greater than +/- 2 tonnes cannot normally be achieved, leading to substantial possible errors. In the case of heel weight estimation this makes it difficult to achieve "right first time" batching when changing alloy resulting in a second or third alloy composition adjustment step being required. This results in a significant loss of productive furnace time with each step adding a further 30 – 60 minutes to the batch cycle.

Where transfers are made from a melting furnace to a holding furnace again the amount transferred is estimated visually. The consequence of transferring too little, either due to overestimating the residual heel weight or overestimating the amount transferred is to cast the ingots short which in extreme cases results in the whole cast being scrapped with a significant loss of yield and increased costs for remelting. Because of the undesirability of casting short casthouses generally build in some safety margin in the batching calculations and also in the estimating process with the consequence that there is a built in bias to casting long giving rise to a systematic yield loss.

To overcome these difficulties various systems have been proposed including measurement by using a radiation beam such as laser or radar or the use of load cells (1). Radiation beam techniques have generally failed to achieve reliable results because of the presence of varying quantities of dross on the surface of the molten aluminium and adhering to the furnace walls making accurate determination of level difficult. Furthermore, when it is possible to obtain an accurate measurement of the metal level the heel weight still has to be calculated from the volume of metal existing beneath the surface of the melt and significant errors can occur due to build ups of dross adhering to the hearth or refractory wear resulting in reduction of the hearth thickness. Load cells, also, cannot distinguish between build ups on the hearth and walls and liquid metal thus resulting in the need to frequently re calibrate or estimate the build up. Nether can they be realistically retro – fitted but have been supplied with furnaces when initially installed however subsequent difficulties with maintenance often result in their becoming damaged leading to their subsequent abandonment.

The key issue for solutions proposed so far has been how to overcome the difficulty in measuring build ups on the hearth or changes in the hearth weight or geometry due to wear. Without a means to accurately take account of such changes any measurement of heel weight can be subject to errors of up to several tones in weight.
A new system, BatchPilot has been developed (2) which operates on the principle of detecting changes in the furnace cylinder hydraulic pressure and angle in tilting

Basic Principles

Figure 2 presents a schematic view of a typical tilting furnace. In operation, the furnace is supported by its pivots and up to two hydraulic cylinders. Therefore, the furnace mass is distributed between the furnace pivots and the cylinder(s). The proportion obviously depends on the location of the centre of gravity of the whole system and can be obtained by straightforward calculations. Due to the geometry of the system, a large furnace angle corresponds to a larger pressure in the cylinder.

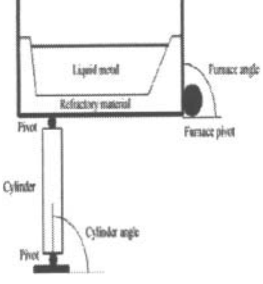

Fig. 1 Schematic diagram of a tilting furnace

At first glance, weighing the liquid metal inside the furnace using the hydraulic pressure in the cylinder seems rather simple. Indeed, knowing the pressure when the furnace is empty, one could establish a correspondence between the pressure variations caused by various amounts of liquid metal to determine the actual metal mass inside the furnace. However, several other parameters must be taken into account in order to obtain an accurate measurement.

First, friction plays a significant role in such a system. Indeed, the overall weight of a tilting furnace can be as high as 500 metric tons, imposing a friction force in the various pivots as well as in the cylinder seals. Secondly, leaks, which are always present in hydraulic systems, can make the furnace move slightly over a period of time. Since pressure in the cylinder depends on the furnace position, this can prevent accurate measurements to be obtained.

Friction effects can be eliminated by measuring pressure dynamically while forcing the furnace to move, however, the problem then becomes more complex as the centre of gravity of the furnace and that of molten metal move as the furnace angle changes. Furthermore, deposits of dross accumulate on the furnace walls ands significant build-ups weighing several hundreds of kilo's can be observed over the course of a single day. This creates a "dead" mass, adhering to the furnace walls, that does not move when the furnace is tilting as opposed to the molten metal and influences the pressure accordingly.

A series of fundamental experiments (2) were performed in order to get information on the characteristics of the system. The relationships under dynamic conditions between pressure and furnace tilt angle, pressure versus time and furnace position versus time were studied allowing a comprehensive model to be developed which could be used to determine accurately the weight of molten metal in the furnace.

In practise the BatchPilot system software is able to characterise any furnace by means of conducting a series of calibration measurements with the furnace completely empty and full. Once characterized the system can be used to determine both heel weights and the weight of metal transferred into the furnace continuously during transfer.

BatchPilot has the facility to detect build up of dross on the furnace lining and to compensate for this in determining an accurate heel weight. In casthouses with a plc controlled process system BatchPilot can be readily integrated into the existing control system.

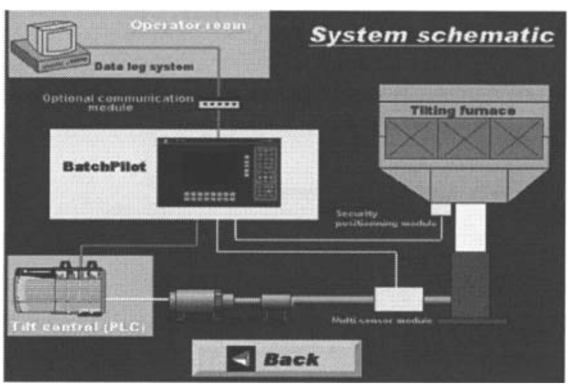

Fig. 2 Schematic of the BatchPilot system

Performance in the Casthouse

Results have been published in detail on the installation and operation in production of the BatchPilot system (3) (4) at two casthouses, Aleris Duffel, and Alunorf respectively. Today Alunorf has equipped all 11 casting lines with the BatchPilot system and their experience is summarized as follows:

Objective

Alunorf wished to optimise the number and sizes of slabs being produced per cast as a means of increasing production capacity. A comprehensive programme of work was therefore instigated aimed at examining the potential for using the BatchPilot system as a means of achieving better control of metal transfer weight and metal weight in the furnace.

Trial Procedure

An extensive programme of assessment and evaluation work on the BatchPilot system was carried out in two separate phases, at the Alunorf casthouse, Neuss.

1st Phase - Measurement

In this phase of the programme:

- Heel weight measurements were made to establish the inherent BatchPilot system accuracy and variation between measurements.
- To achieve this three different furnace casts were used and the same heel weights measured five times each on each of the three casts.

The procedure used to make a heel weight measurement was to raise and lower the furnace twice through a cylinder travel of 100mm in 60 seconds. This is a very low tilting speed, less than the slowest speed used for casting, and therefore it was necessary to adjust the settings for the hydraulic cylinder proportional valve to allow an additional new slower speed to be adopted for the BatchPilot measurements. The BatchPilot software averages the two measurements to give a final heel weight measurement which appears on screen. The purpose of this procedure is to avoid the effect of variable frictional forces that would be present if static measurements were made; instead measurements are taken during the stable phase of the pressure vs tilt angle curve. The same procedure is used for measuring full furnace weight.

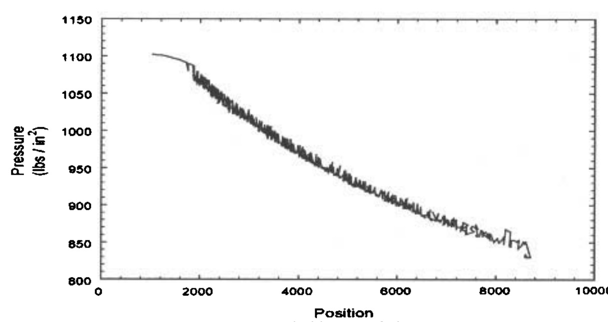

Fig.3 Pressure vs position (arbitrary units) curve

The results are shown in table 1.

FURNACE No.	SGA06	SGA06	SGA06
CHARGE No.	112714	112750	112674
1.Heel measurement	16.0 tonne	0.5 tonne	2.7 tonne
2.Heel measurement	16.2 tonne	0.8 tonne	2.7 tonne
3.Heel measurement	16.3 tonne	1.1 tonne	2.8 tonne
4.Heel measurement	16.5 tonne.	1.2 tonne	3.0 tonne
5.Heel measurement	16.5 tonne	1.2 tonne	3.2 tonne
	Delta G = 0.5t	Delta G = 0.7t	Delta G = 0.5t

Table 1. Heel weight measurements with BatchPilot in 1st Phase work

The findings were:

- Delta G ranged from 0.5 t to 0.7 t.
- The variation from the first measurements to the last (drift of measurements with time) was thought to be due to dross build up in the hearth but nevertheless still within the claimed accuracy of the BatchPilot system.

2nd Phase – Analysis

In this second phase of the work:

- Heel weight, transfer weight, total furnace weight and slab weight were measured and calculated on twenty furnace casts. From these results Figure 4 is a plot of the difference between the measured full furnace weights and the calculated sum of slab weight and heel weight.

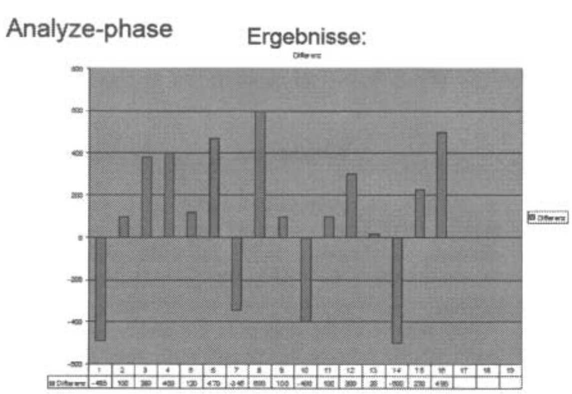

Fig. 4 Differences between measured and calculated furnace weights

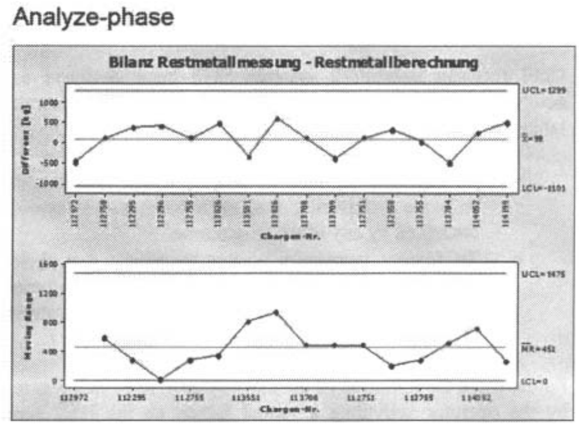

Fig. 5 Statistical plots of measured furnace weights versus calculated furnace weights showing difference and range.

In the above figure the X-axis is shown in kg, and the Y-axis denotes the charge No. The terms UCL and LCL represent "Upper control limit" and "Lower control limit" respectively. The upper chart shows the crude difference in kg between measured furnace weight with BatchPilot and the calculated furnace weight. The calculated furnace weight is the sum of the weights of the cast ingots and heel weight remaining in the furnace

The lower chart shows the moving range which is +/- 451kg

Conclusions from Phase 2 work

- BatchPilot measurements are within 1% of the total furnace weights
- This agrees with the BatchPilot system specification which indicates an accuracy of 0.5 to 1.0%

Benefits to Alunorf of the BatchPilot System

These are summarised by the Aluminium Norf GmbH Management as follows:

- Total furnace weights of around 45mt can for the first time be measured accurately
- Frequency of furnace cleaning is now more manageable due to immediate availability of BatchPilot measurements
- Using BatchPilot measurements it is now possible to routinely cast three 1650mm slabs per cast. This was not possible before.
- Since the introduction of BatchPilot there have been no "short cast slabs"
- Alloy changes are easier to manage as the heel weights in the furnace are accurately known because of BatchPilot measurements
- Overall production capacity at the Alunorf casthouse plant has been markedly increased by the introduction of the BatchPilot system

Recent developments to the BatchPilot system

Until recently BatchPilot systems have been designed to be completely stand alone from customers facilities. The reasons for taking this direction were:

- To maintain the integrity and stability of the BatchPilot software – ensuring that each programme cannot be corrupted by any other programme.
- To respect customers wishes to ensure that their IT networks and furnace plc's were not linked in order to avoid any potential problem with either de stabilising the other.

Furthermore the initiation of the measurement sequence was made by the operator activating a virtual button on the HMI screen. Thus both the transfer of information from the BatchPilot plc to the batcher and the operation of the measurement sequence were manual.
The objective of the current development was to completely *remove the need for human intervention through:*

- Automation of measuring process
- Integration of BatchPilot output data into customer batching system

Automation of measuring process

In the latest systems installed, when the furnace sits down at the end of cast a "system active signal" is generated remotely within a few seconds which triggers the BatchPilot measurement sequence. A Siren and flashing lights warn operators that measurement is in progress and thus the measurement becomes an automatic part of the finish cast sequence.

Integration of BatchPilot output data into customer batching system

Heel weight measurements can now be sent automatically to a client batching system, allowing the batcher to accept an actual weight rather than rely on the batching programs cumulative estimated heel weight.

To achieve this a secure bridge was designed to read data from the BatchPilot PLC and transmit this to the client batching system. The secure bridge connection was achieved by using an Ethernet/IP to DF1 Gateway communication module. This module creates a function to share a data exchange table without the risk of destabilising BatchPilot or client systems. A custom program was also designed to transfer and store the data and this was installed on the clients IT server. This program reads the time stamp of the last heel measurement and when there is a date change an ASCII file is created that sends the last heel measurement to the client batching system. When the next batch is then being created the operator has the option to accept or decline the measurement.

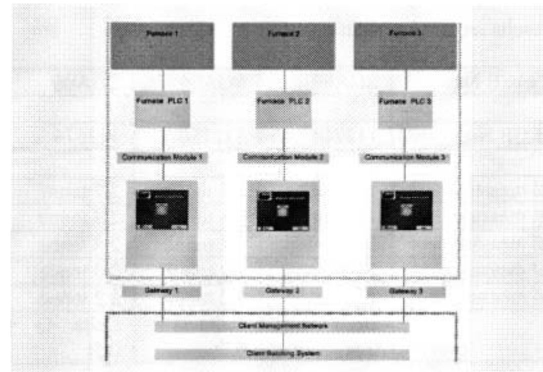

Fig. 6 Integration of BatchPilot into client networks

Discussion

When initially developed and introduced BatchPilot was seen as a means of providing a more accurate estimate of furnace heel or transfer weight than had hitherto been available: given as noted in the introduction that the best accuracy that can be achieved with a visual estimation by the operator is +/-2,000kg any system that can produce a result somewhere near to +/-500 kg is a significant step forward. Also it was found particularly helpful when cast aborts or other operational problems lead to a half full furnace, these being particularly difficult for operators to estimate with any accuracy. In many cases this helpful tool mode was considered to be a success however unless the data from the system can be automatically introduced into the batching calculations and measurements made without fail on every cast the system cannot achieve it's potential to become a fully integrated part of the casting process.

Therefore the next step to achieve full automation of the measuring cycle and integration of the data from BatchPilot into the batching calculation was deemed essential to achieve the full benefits of furnace weighing and to see these reflected in terms of measurable key performance indicators such as % "right first time" analysis and reduction of % scrap due to short casts and yield loss.

Conclusions

1. A system of measuring furnace heel and transfer weights has been presented which can achieve an accuracy of between 0.5% to 1.0% which means measuring the weight of a 50tonne full furnace to +/-500kg
2. A key feature of the system is it's ability to recognise build ups on furnace hearth and walls thus eliminating potential errors in the heel weight measurement
3. The recent development of a capability to achieve full automation of both the measuring cycle and the transfer of data on heel weight into the batching calculation will greatly facilitate improvement in key performance indicators such as % "right first time" batching.

Acknowledgements

The author wishes to thank the Management of Aluminium Norf GmbH for permission to publish this work.

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