Latest developments in recycling aluminium dross and scrap using tilting rotary furnaces

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The paper discusses the latest developments in aluminium recycling using tilting rotary furnaces (TRF) taking as reference a new 30 000 TPY secondaries plant in France. The plant is equipped with two 12 tonne TRF for melting general commercial scrap and a 7.5 tonne TRF primarily used for melting aluminium dross together with two 30 tonne refining/holding furnaces, swarf dyer, casting equipment and automated ingot stacker. The paper also compares the new plant with the owner's original plant that is equipped with traditional fixed axis rotary furnaces (FARF).

TRF melting furnaces and charge machine Prémery

Background history

The SNR company was founded about 40 years ago on a site 50 km to the west of Paris in St Arnoult. The plant is equipped with:

- 3 fixed axis rotary furnaces. Unit capacity: 7,500kg. Melting under salt bath
- 1 Holding/refining furnace: Capacity: 20,000 kg
- 1 linear ingot casting machine: Capacity: 6,000 kg/h

- 1 Swarf dryer: capacity 2,000 kg/h

The annual production capacity at St Arnoult is at present approximately 15,000 tonnes and each shift operates with 11 people. The plant specialises in gravity and pressure die alloys.

It is impossible for a company to remain 'static' even in (some would say especially in) the present economical climate and the SNR company took the decision to increase their production volumes considerably to meet a very strong demand from the automotive sector.

The company could not grow further on their original site and so after 3 years of research, reflection and equipment comparisons SNR took the decision to locate their second aluminium refinery at Prémery, 250km south of Paris, on a 'brownfield' site previously operated by Bostik (the glue manufacturers). SNR have invested 7 million euros in the new plant.

The company's objectives in giving itself the opportunity to design a plant on a 'clean sheet' were:

- to create a coherent, high performance production tool
- to be able to process the whole range of commercial scrap including dross using 'salt free' techniques

During the three years of preliminary study, SNR reviewed the different options and latest melting practices offered by the market: reverberatory furnaces (with and without pumps), dry hearth furnaces and tilting rotary furnaces before opting for the latter solution.

Tilting Rotary Furnaces

A tilting rotary furnace is in fact an 'inclined rotating well' which associates the benefits of rotary furnaces, reverberatory furnaces and dry-hearth furnaces in a single machine. In fact, the concept of these furnaces has been around for a long time and was used before the Second World War in the copper industry. However, the technology of the time was not able to extract the full benefit from this simple but ingenious design. Today, with advances in mechanical engineering, hydraulics, refractories and particularly process control, the concept can reveal all its advantages:

- Eliminating or greatly diminishing the need for salt and/or flux in the melt process
- Improving working conditions for furnacemen
- Melting a wide range of feedstock:
- Diminishing or eliminating metal 'pollution' by trace elements in the charge (by free iron for example)
- Facilitating charge mixing and homogeneity
- Promoting lining 'self cleaning'
- Offering low energy consumption and high thermal yields.
- Ensuring faster melt rates: 2 to 3 times higher than traditional furnaces

Tilting rotary furnaces compared to fixed axis rotary furnaces

If we compare the concept of the tilting rotary furnace (TRF) with the traditional fixed axis rotary furnace (FARF) the advantages are evident. The chamber of the FARF is nothing more than a rotating tube or corridor, with in its simplest form, a burner at one end and a flue at the other. The furnace operates under negative pressure and draws in cold 'parasite air' from outside the chamber thus making it virtually impossible to control the atmosphere of the furnace which is nearly always oxidizing (air rich). This condition makes it necessary to use large quantities of salt (NaCl/KC) to protect the charge and obtain acceptable metal yields. The charge, as it approaches liquidus, remains more or less static. As with all high temperature furnaces heat transfer is achieved primarily by radiation and re-radiation (via the refractory lining) but not as efficiently as in a TRF.

The TRF furnace on the other hand is closed chamber having a single entrance and exit point. The door carries the burner and the flue. The furnace operates under positive pressure and when the burner is firing there is a total absence of parasite air ingress, therefore the furnace can operate in a slightly 'reducing' (gas rich) atmosphere which eliminates the necessity to use a protective salt cover. Additionally, as the furnace operates at an angle, the charge is 'mixed' with a similar action to that of a concrete mixer. This improves homogeneity and heat transfer resulting in very high thermal efficiency.

Dross Engineering furnaces

SNR compared the tilting rotary furnaces offered by several suppliers before opting for those designed and built by Dross Engineering.

The characteristic aspects of Dross Engineering's TRFs are:

- Compact Design
- Maximum use of rotating unions, eliminating the use of flexible hoses.
- Onboard control panel, power pack & air blower
- Self supporting chassis
- Eliminating need for expensive foundations
- Positive & direct drive
- Vari-gas burner control system
- New generation temperature control

The TRF units built by Dross Engineering have found applications across the range of non-ferrous industries and are used to melt zinc and aluminium and reduce lead, tin and bismuth oxides thus showing the remarkable versatility of this furnace concept.

The SNR Prémery Plant

The layout of the plant in Prémery has logical structure and divides the foundry into 'activity zones'.

- Materials receiving, stocking and 'cold refining'

- Materials preparation: Swarf Drying 2000 kg/h
- Melt shop: 2 x 5m3 (12,000kg) and 1 x 3m3 (7,500 kg) tilting rotary furnaces. Two charge machines feeding all 3 furnaces. Melt rate for each furnace: 3,000kg/h
- Refining: 2 tilting holding furnaces 30,000kg each
- Casting/ingot stacking: 1 linear casting machine 6,000kg/h, automated stacker, and a liquid metal transport station for 14 road transport ladles.

The melting and charging plant, holding/refining furnaces, casting and ingot stacking equipment, swarf drying etc.. are supplied by Dross Engineering. The Prémery plant has an annual capacity of 30,000 tonnes and employs 7 foundrymen per shift.

Pollution Control

The plant is equipped with a bag house filter designed by the French subsidiary of the German company: INTENSIV. The company has a long history designing dry process particulate arrestment for the cement industry, foundries and mines etc… The particularity of the INTENSIV bag-house system is their dual stage reverse air cleaning which ensures optimum performance and low compressed air consumption. In the case of the SNR Prémery plant the media used and the reverse air system enable particulate emissions of less than 0.5mg/Nm3 to be achieved.

Filtration capacity: 140,000m3 @ 110˚C

Additionally the swarf drying unit is fitted with and after burner unit and ‘quench tower’ to avoid formation of NOX.

Choice of Combustion Equipment for TRF

A major consideration in any installation of this type is the choice of combustion system. For tilting rotary furnaces there are basically two options:

Air-Gas (or Oil) burners

Oxy-Gas (or Oil) burners

Most fabricators of this type of furnace fit oxy-fuel burners giving as arguments in favour of such a choice:

- Increased production rates
- Reduced fuel consumption
- Reduced volumes of combustion products, therefore smaller baghouse/filter requirements
- Increased available heat
- Quasi elimination of NOx

However, before making a final choice the end-user should take into consideration other points that are not so favourable:

- Higher equipment costs (gas train stainless valves etc…)
- Oxygen costs and constraints (after all air is free!)
- Burner control issues
- Plant safety
- Refractory life

Those who have a long experience in the industry can testify to the fact that 'there is nothing new under the sun'! 20 or more years ago the trend (in France and Europe) for Secondary Smelters was to equip their furnaces (all their furnaces; rotary and dry hearth) with oxy-gas burners. Effectively improved production rates were achieved (the furnaces were hotter and so melted at higher rates) and improved consumption rates were recorded. But at what cost? Equipment and refractory problems and safety issues had for consequence that all installations reverted to air-fuel burners. Why? Combustion control of oxy-fuel burner systems is extremely specialised and, at the time, the systems available lacked the computing power and programme depth for such burner systems, within the specific application of secondary aluminium smelting in the furnaces of the period, to be really successful.

Oxy-fuel presents considerable advantages provided the combustion control system is sufficiently well adapted and also operator friendly.

Additionally, for the particular project in question, SNR requires that the new plant operates 'salt-free' in order for them to have the possibility to commercialise the residual ash. Therefore, it became imperative for them in choosing the combustion system to be sure that the oxy-fuel burners could benefit from the innovative control system developed by Dross Engineering: Vari-Gas

Pouring from TRF Prémery

The advantages of the Vari-Gas system

The Vari-gas combustion control system, originally developed for air-fuel burners by Dross Engineering and the software engineers of their industrial partner, PELSS enables the end-user to:

- Choose the burner power setting (max, mid-range or low) and to define intermediary power settings
- Set the furnace 'atmosphere': slightly reducing (excess gas), neutral (stoichiometric), or slightly oxidizing (excess air)
- Define and save to memory an 'atmosphere curve' in relation with the type of products to be melted. For example: the melt programme for charge of contaminated feed stock could start off 'oxidizing' change to 'slightly reducing' and finish 'neutral'.

All these operations are programmed using a few keys on the operator interface.

The Vari-Gas system is primarily a furnace control tool that, in the hands of an experienced furnaceman , enables exceptional thermal and metal yields to be obtained.

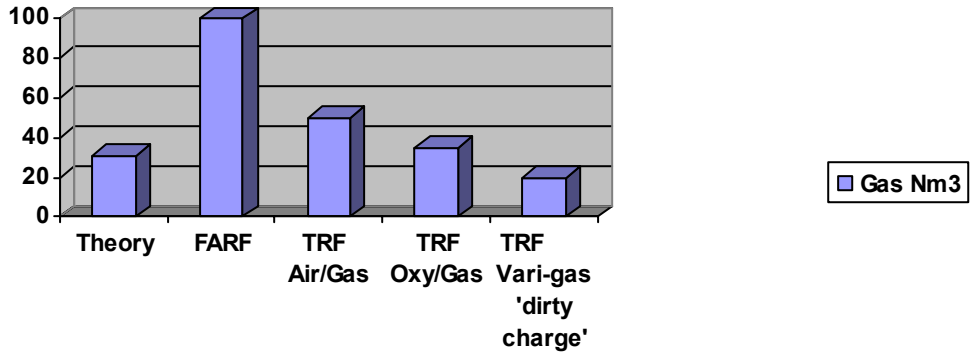
Fuel Consumption

As we have already seen, the basic concept of tilting rotary furnaces lends itself to high thermal yields. Heat transfer rates to the charge by radiation (and re-radiation) and conduction are optimised. When these types of furnace are fitted with oxy-fuel burners, reduced N2 concentrations result in stronger gas radiation and there is a considerable increase in the heat available to melt the charge (approximately 50% more in relation to air gas burners at temperatures of 1100˚C with 95% pure oxygen and natural gas). But it is worth noting that higher 'localised' flame temperature is not the only way to achieve higher heat transfer rates and thus improved productivity, increased 'ambient' temperature has a greater effect. Oxy-gas burners available today give good flame homogeneity and greater uniformity between flame and furnace temperatures. With Air Liquide's Albatch burner a highly luminous flame is produced that is up to 3 times wider than conventional oxy-gas burners. Fuel and oxygen are introduced into the furnace through separate injectors with the oxygen being injected above the fuel to improve stability, prevent 'lofting' and reduce flame peak temperature. Thermal decomposition of the fuel is improved leading to the formation of highly radiant carbon particles.

If we were to compare the thermal yield and fuel consumption with a fixed axis rotary furnace fitted with a traditional air-fuel burner, there is in fact 'no comparison'. The concept of the fixed axis rotary is well known for its mediocre thermal yield and, in addition, the salt bath requires heating before you even begin to melt the charge of metal.

Theoretically, the energy required to melt one tonne of aluminium is 310kW at 100% efficiency, i.e. 31Nm3 of natural gas (with a LCV of 10). In a fixed axis rotary with an air-gas burner, thermal efficiency is very poor and energy consumption per tonne melted are in the region of 100Nm3 natural gas (minimum). On the other hand in a TRF with optimised thermal efficiency energy returns of 50-60Nm3 with an air-gas installation and 35-38Nm3 (plus 70 – 75Nm3 oxygen) can be expected. When using the Vari-gas system, if the charge

contains organics such as grease, lacquer etc… it is possible to exploit this 'latent' energy rather than sending the unconsumed hydrocarbons to the bag-house filter; In such cases we have recorded energy returns of less than 20Nm3 (in some cases as low as 12Nm3) per tonne melted.



Metal yields

It is difficult to talk about metal yields for the many different categories of aluminium scrap as there are far too many variables. However for melting a charge of clean new cast we have recorded yields in excess of 97%. The operator of the two site in question, Prémery and St Arnoult, confirms that over the range of scrap recycled through the two plants they have recorded improved yields of several percentage points at the TRF site (Prémery) as opposed to the site operating fixed axis rotaries (St Arnoult) and there is the considerable additionally advantage of 'salt-free' operation at Prémery.

Conclusion

The tilting rotary furnace is proving itself to be a high performance production tool enabling both secondary metals smelters and foundries to benefit from considerably improved production (up to 45%) and fuel savings (over 50%). SNR's production facility at Prémery came on stream in Summer 2005 and now operates 3 shifts daily. The company's objectives in significantly increasing their production being met:

- to create a coherent, high performance production tool
- to be able to process the whole range of commercial scrap including dross using 'salt free' techniques