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REDUCTION IN TOTAL ENERGY CONSUMPTION AT CORUS ENGINEERING STEELS – A SUCCESS STORY UTILISING VALUE ADDED TECHNICAL SUPPORT

OBNIŻENIE CAŁKOWITEGO ZUŻYCIA ENERGII W CORUS ENGINEERING STEELS – HISTORIA SUKCESU WKORZYSTANIA WSPARCIA TECHNICZNEGO WARTOŚCI DODANEJ

A Value Added project to look at energy consumption commenced with a Total Energy Audit looking at all energy inputs to the melting furnaces within the CORUS group. This identified Aldwarke Melting Shop (AMS) as a high-energy user with large variations in the data.

The Graftech approach to Total energy[1] counts all energy inputs to the furnace, including electricity, oxygen, gas, iron, DRI, hot metal etc, and gives each a kWh equivalent. The total is compared to a database of worldwide electric arc furnaces taking into account negative factors on energy consumption and then if considered high, reasons for possible inefficiencies are studied.

During 2006 and early 2007 various tools including furnace observations, electrical measurements, VM2^{TM} analysis, chemical energy program, cooling water & offgas studies were used resulting in a significant downward trend.

The paper discusses the journey from upper quartile in the distribution of total energy to median for an engineering steels producer experiencing negative factors affecting energy consumption, with the result being a 17% reduction in total energy, whilst at the same time reducing power on time and increasing productivity.

Keywords: Arc furnaces, energy, efficiency, carbon

Projekt Wartość Dodana dotyczący zużycia energii rozpoczął się wraz z wewnętrznym Audytem Całkowitej Energii w grupie CORUS, odnoszącym się do energii pobranej do pieców w celu roztopienia wsadu. Zidentyfikowało to stalownię Aldwarke Melting Shop (AMS), jako źródło zużycia dużych ilości energii z dużymi wahaniami danych.

Podejście firmy Graftech do całkowitej energii [1] uwzględnia każde pobranie energii w piecu, z uwzględnieniem energii elektrycznej, tlenu, gazu, żelaza, DRI, ciekłego metalu itd. i każdemu czynnikowi przyporządkowano ekwiwalent kWh. Całość jest porównywana z bazą danych elektrycznych pieców łukowych na świecie, biorącą pod uwagę czynniki wpływające ujemnie na zużycie energii, a następnie jeżeli są wysokie, badane są możliwe przyczyny występowania.

W roku 2006 i na początku 2007 użyte były różne narzędzia, z uwzględnieniem obserwacji pieca, pomiarów elektrycznych, analiz VM2^{TM}, programu chemicznej energii, badań nad chłodzeniem i gazami wylotowymi, doprowadzając do znacznego obniżenia trendu.

W artykule omówiono przejście od górnego zakresu w rozkładzie całkowitej energii do wartości średniej, dla produkcji stali, z uwypukleniem wpływu ujemnych czynników na zużycie, co spowodowało 17% obniżenie całkowitej energii, z równoczesnym obniżeniem mocy i zwiększeniem wydajności.

1. Introduction

N furnace at CORUS Aldware Meltshop (AMS) was identified as a high consumer of total energy, being in the 650 – 690 kWh/t range, following a Total Energy audit in 2005.

During Q1 2006 various tools were used to study the furnace operation to try and explain why and where energy usage was inefficient and to set in motion a programme of modifications to improve efficiency.

The paper details the tools used to study energy consumption and the steps taken towards the resulting 17% reduction in Total Energy, which despite the technical advances in EAF equipment in recent years is in no small part due to attention to logistics and the chemical

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reactions and laws of physics that underpin steelmaking or “back to basics” steelmaking.

2. Total Energy Approach

The Graftech approach to total energy [1] is to count all energy inputs to the electric arc furnace with kWh equivalents being given to all chemical and other inputs.

Input levels are then benchmarked against a database of worldwide EAF’s taking into consideration factors affecting energy consumption for a specific EAF. In the CORUS case the engineering steels product mix involves some extended refine times in the EAF.

Total energy consumption (kWh/t liq) = *electrical (kWh/t)*

+ 10.5 * *gas* (Nm^3/t)
+ 5.2 * {O_2 (Nm^3/t) – [2 * *gas* (Nm^3/t)]}
+1.1* *pig iron %*
- 1.0 **DRI %* (1)

CORUS AMS N Furnace

N furnace is a 7.2 m diameter 165 t EBT furnace with a 120 MVA transformer. Chemical energy is via 4 VLB’s (**V**irtual **L**ance **B**urners), a conventional burner, manipulator ($1O_2$+ 1C) and 2 carbon injectors as per the layout in figure 1. Fluxes are added via the 5th hole.

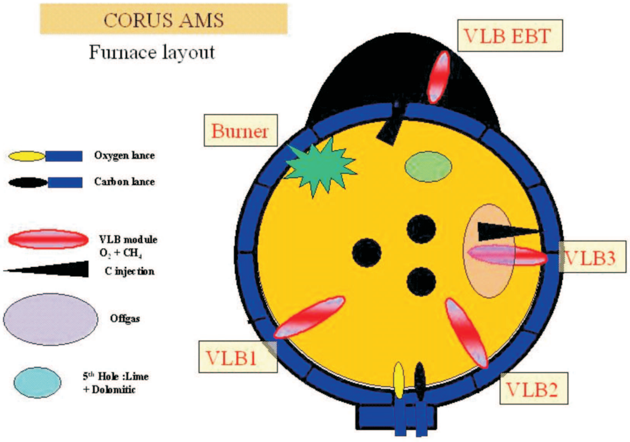
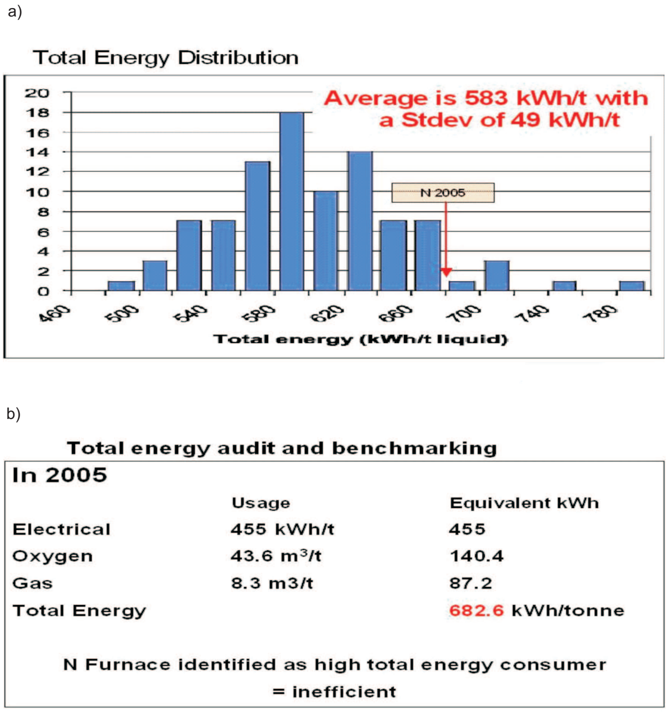


Fig. 1. Furnace lagout

The total energy audit carried out in 2005 identified N furnace as a high consumer with an average of 683 kWh/t vs the mean of the database distribution of 583 kWh/t. fig.2a illustrates the 2005 average vs the database distribution and fig 2b. the breakdown of the 683 kWh/t into electrical and chemical energy.



Total energy audit and benchmarking

In 2005

	Usage	Equivalent kWh
Electrical	455 kWh/t	455
Oxygen	43.6 m³/t	140.4
Gas	8.3 m3/t	87.2
Total Energy		682.6 kWh/tonne

N Furnace identified as high total energy consumer
= inefficient

Fig. 2. Average vs. the database distribution a) break down of the 683 kWh/t into energy b)

3. Tools used to investigate energy consumption

3.1. Losses to water-cooling.

By measuring the inlet, outlet temperatures and flow rate of water to roof, panels and Elbow (FT1), the MW loss to the water-cooling can be calculated (see equation (2)) and plotted as shown in fig. 3.

MW loss = {δT (^{o}C) * water flow rate (m^3/h) * 1.162}/1000 (2)

Specific heat capacity for water = 4.184 J/g and 1 kWh=3.6 kJ

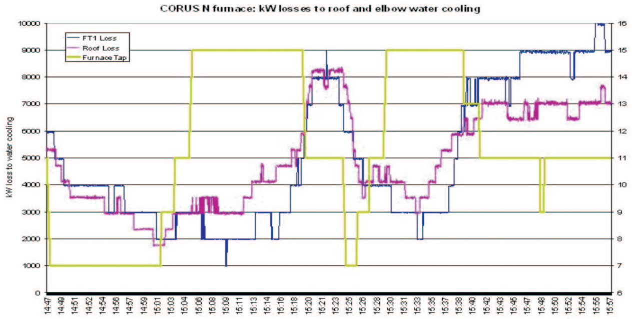


Fig. 3. Energy lesses to voof and elbow water codingy

3.2. Off gas temperature

A simple plot (see fig.4) of the off gas temperature was also useful in analysing periods when energy was being wasted, however, because of the sensitivity of this temperature it was also found to give an indication of the end of the C + O_2 reaction during refining as the temperatures shows a significant decline when there is limited carbon left for the reaction and hence a reduction in CO/CO_2 generation.

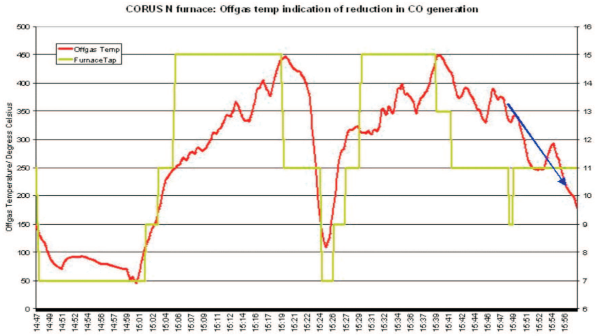


Fig. 4. Offgas temperature

3.3. VM2 ^{TM} [2] data analysis

VM2^{TM}allowed us the capability to collect together electrical data via an industry standard power meter along with chemical energy and other furnace performance data collected from plc addresses in one place. In addition a WEB based reporting system allows anything from detailed individual heat analysis to convenient daily, weekly or monthly reports to monitor longer-term trends.

Figure 5 shows two screens from VM2^{TM} WEB reporting showing detailed electrical data for an individual heat and a long-term plot of average phase currents used to monitor consistency of current balance and regulation performance.

Heat# 7456

2008-Jan-29 11:48:38 to 2008-Jan-29 13:02:23

Type Line

☐ Active chart

Variables to plot

kWtot ☑ SecI ☑ THDAverage ☑

FurnaceTap ☑ (None) ☐ (None) ☐

Fig. 5. VM2^{TM} real time heat trend chart

The MW loss and off-gas temperature plots were added during the process as custom variables and are available alongside the standard data.

4. Furnace observations

Time was spent observing and taking notes on furnace operation, with particular emphasis on charge carbon placement, chemical energy practice, fume/offgas observation, scrap loading and listening to differing opinions of the various personnel involved.

Some very interesting areas for potential improvements came out of this and mostly a requirement for "back to basics" after restructuring and retirement losses of experience. These included:

1. basic steelmaking chemistry knowledge
2. logistics – people in right place at right time
3. carbon positioning and scrap layering issues

The main lesson learnt from this was that not everything could be achieved by data analysis alone.

5. Underpinning reactions and principles

Carbon and oxygen reaction

The most efficient and desirable return from carbon is the reaction with oxygen when it is in solution in molten steel and therefore is the reason why cast iron gives an energy benefit. Fig. 6 includes the desirable position for the C + O_2 reaction.

Thus the primary aim with charge carbon is to get it as low in the basket as possible, whilst avoiding violent reactions during charging and losses through the basket "leaves". This gives it the best possible chance to get into solution to release maximum energy.

Post combustion

Post combustion relies on the energy released from the combustion of CO to CO_2; however, efficiency relies on the released energy being usefully absorbed into the scrap. Due to surface area effects this potential reduces with scrap size.

Burner operation [4]

Burners transfer energy mainly by conduction and therefore efficiency reduces as there is less scrap around the burner and energy transfer is by radiation.

In the case of radial burners, once they have burnt through to the electrode cloverleaf they are heating electrodes, roof and delta.

In general burner efficiency lasts for about the first third of each basket.

Arc voltage and carbon level [3]

During the refine period the ability of the liquid steel to absorb energy and hence increase temperature is related to both carbon level and the arc voltage of the electrical set-up.

Slag FeO and foaming slag

Temperature pickup during refining and losses to water-cooling and fume system are dependent on good foaming slag conditions. If oxygen is unable to react as desired with dissolved carbon, it will react with Fe forming FeO.

Whilst FeO in the slag is required to a certain level too much will create a "watery" slag, which is unable to retain the CO bubbles created from the reduction of FeO by injected carbon and thus will not foam. With unshielded arcs and "watery" slag, refining becomes extremely energy inefficient. Fig. 6 shows the chemical reactions involved in slag foaming.

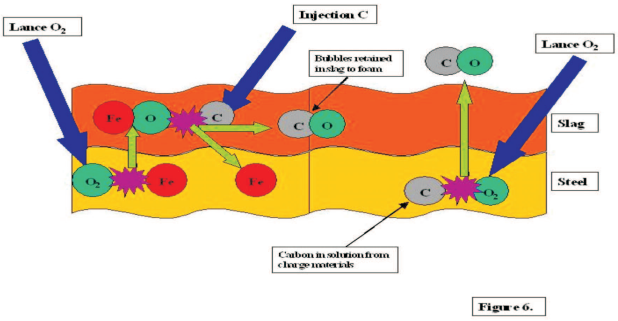


Fig. 6. Chemical reactions involved in the slag foaming

6. Changes to furnace operation

Using the various tools detailed above it was determined that there were significant energy losses to the water-cooling and fume system equivalent to flat bath conditions throughout 1^{st} and early 2^{nd} baskets.

The potential to improve the efficiency of the refine period was also identified.

The various options that were used to attempt to reduce losses during these periods are listed below.

Charge carbon

Observations in April 2006 rated heats good/medium/poor on carbon position in the basket and the first finding was that despite carbon being put in the correct layer as requested by the system, there was a large range of physical positions dependant on the density of scrap in layers below the coke.

Although at the time there was still a lot of "noise" on performance data heats rated good averaged 6 MWh & 7.5 minutes less on power on time than those rated poor.

The "good" heats also used more oxygen, which was attributed to the fact that the transition from burning to lancing mode on the VLB's is controlled by arc stability and due to more efficient return from the charge carbon causing these heats to reach stable arcing conditions earlier.

Another feature of these heats was the lower level of MW loss to the roof during 1^{st} basket. This was attributed to more of the charge carbon going into solution in the steel as desired rather than burning high up in the furnace with limited transfer of energy to the scrap.

In May 2006 control of charge carbon input was shifted to physical position rather than a fixed layer.

VLB setup

It was noted that VLB and burner settings were non-stoichiometric and later confirmed that this was a "post-combustion" setting. In Feb 2007 the VLB's were set to stoichiometric during burning mode.

In addition several options were discussed to reduce oxygen input via lancing. Delay analysis indicated that VLB2 area was suffering panel damage and in late Dec 2006 the decision was made to remove it. This reduction in chemical energy input proved to be the single most significant step of the process.

Power programme

Shorter more powerful arcs were introduced on Tap11 (1000V) during refining, reducing arc voltage during this period and aiding temperature pickup.

The period on Tap15 (1200V) during 1^{st} basket was also extended.

Offgas temperature graphical display

This had been just a displayed number on a screen. This was altered to a graphical display of the last 30 minutes thus, enabling the operators to judge when the CO/CO_2 generation had slowed and thus an indication of when to adjust the oxygen lancing level to reduce excess oxygen levels in the steel.

Back to basics

A concerted effort on education and logistics led to significant improvements in scrap layering and reduction in power off time along with unnecessary extension of power on time during refine. This has had a continuous contribution over the period to the downward trend.

7. Results

N furnace

Fig. 7 illustrates the progression of the total energy through 2006/07 with the major steps identified. It

TABLE

N furnace performance progression 2005-2007

Parametr	Q4-2005	Q1-2006	2H-2006	Q1-2007	Q2-2007	Q3-2007	Q3-2007 vs Q4-2005
ElectricalkWh/t	455	451.1	437.3	432.8	419.4	417.1	-8.3%
$O_2 m^3/t$	43.6	40.5	38.8	30.8	29.6	29.3	-32.7%
Gas m^3/t	8.3	7.4	7.3	5.5	5.5	5.4	-34.9%
Total kWh/t	68.3	662.6	639.8	593.3	573.7	569.8	-16.6%
Pon Time	58.1	56.5	56.0	54.1	53.7	52.8	-9.1%
12t(eletrode tip consumption)		2864	2724	2739	2674	2671	-20.1%
Tonnes per hour	82.5	82.5	87.6	101.6	102.4	100.8	+22%
Tonnes per heat	150.5	155.6	155.9	157.5	158.8	159.2	+5.7%
Kg/t (graphite)	2.44	2.15	2.05	2.07	2.02	1.89	-22.5%
PON Stdev	5.47	5.01	4.45	3.81	3.48	3.64	-33.5
MWh Stdev	4.97	4.77	4.02	3.67	3.22	3.33	-33.0

should be noted that there is a major background contribution from efforts on scrap, scrap layering and general good meltshop practice that cannot be attributed to an individual step but are driving the trend downwards.

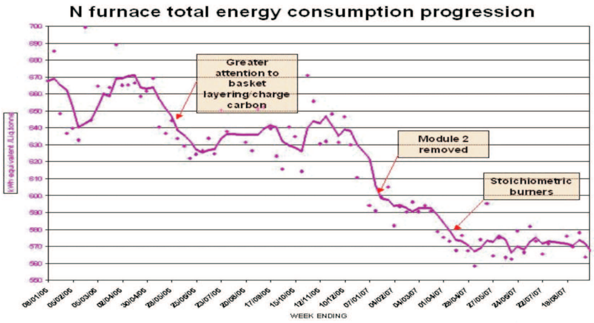


Fig. 7. Progression of the toten energy

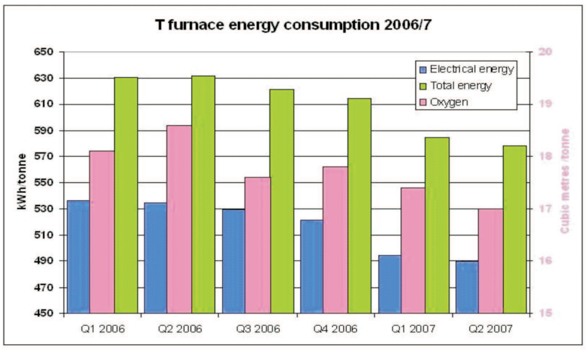


Fig. 8. Energy consumption

Beneficial effect on performance of 2^{nd} furnace

Table 1. shows the progression of the same total energy figure for the other furnace in the AMS meltshop (T Furnace). Although no specific work was done on power programme, chemical energy programme or losses on this furnace it has also seen a significant reduction from a lower starting point.

This is entirely due to the improvements in scrap practices and basket layering and the extension of good practices to the whole shop.

Reduction in carbon dioxide emissions

Figure 9 demonstrates the change in CO_2 emissions from 0.1434 t CO_2/ t.liq steel in 2005 to 0.1134 t CO_2/ t.liq steel in 1H 2007, or a 21% reduction.

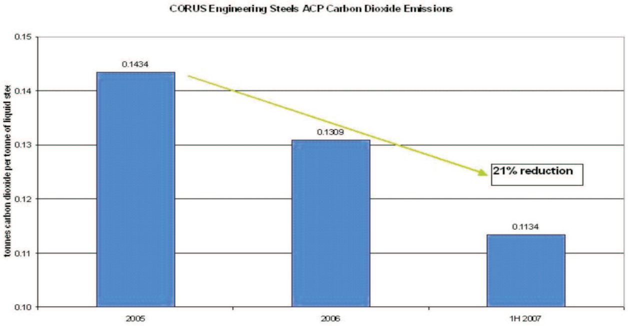


Fig. 9. CO_2 emissions

8. The future

Having stabilised performance at the lower total energy consumption levels future work will include:

1) further development of chemical and electrical energy programmes
2) major investment in scrap quality

3) work on reduction in power off time
4) value in use analysis of raw materials

9. Conclusion

A combination of "back to basics" steelmaking supported by targeted Graftech technical support and data analysis has resulted in ~113 kWh/t reduction in total energy input to CORUS N furnace, or being topical, the equivalent of ~36,000 tonnes per year of CO_2 emissions.

With increasingly complex equipment to deliver chemical energy to the electric arc furnace we are still governed by the underpinning chemical reactions and laws of physics as we always have been. With increasing speed of operation the most difficult input to the furnace to control efficiently is chemical energy.

Data collection and analysis made a significant contribution to reduction in total energy and continues to be vital in avoiding loosing control of the hard won gains.

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