Steam as process gas brings economic benefits to Columbus Stainless

Since the reintroduction of steam to the AOD converters at Columbus Stainless in South Africa, crude argon consumption has decreased. The plant no longer has to schedule its production according to argon availability. It has led to improvements in process times and refactory lifetime. Economic analysis has also shown that the cost saving potential is substantial when steam is strategically used in the process.

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Columbus Stainless steel plant in South Africa

The CLU converter process was developed in the early 1970s[1] in France. Steam is used as a substitute for argon and nitrogen, which are the usual inert diluting gases in the Argon Oxygen Decarburisation (AOD) process. The use of steam makes the CLU process more flexible with benefits such as reduced consumption of expensive argon gas, gas constraint management, use of lower cost raw materials and opportunities for improved energy management in the converter.

At Columbus Stainless in South Africa, the CLU-process was originally introduced in 1995. It was decommissioned in 2002 as the original boiler equipment was worn out and the converters were operated as traditional AOD vessels using argon which had high availability at that time. But in 2007 Columbus decided to reintroduce steam, since the AOD process was too argon consuming for production flexibility. In 2008 steam blowing was recommissioned[2]. Columbus now operates two 120t converters, both with steam blowing capacity **(Fig 1)**.

Fig 1 Columbus twin 120t AOD converters operating with steam as a process gas

Steam in stainless refining

The fundamentals of using steam in the converter lie in the decomposition of steam. The effect of the steam is twofold. When superheated steam is introduced in the converter it is decomposed into oxygen and hydrogen according to the endothermic reaction:

$$H_2O(g) \quad H_2(g) + \frac{1}{2}O_2\ (g)$$

$$\Delta H = +241.9\ \text{kJ/mol}$$ [3]

The hydrogen formed acts as an inert gas to replace argon or nitrogen, while the oxygen oxidises the carbon in the steel. By using steam, consumption of the more expensive argon gas is reduced. This can lead to considerable cost savings depending on the amount of steam used. The use of 1kg of steam substitutes for $1.25Nm^3$ Ar (or N_2) and $0.625Nm^3$ O_2 in the converter.

The second effect is that as the reduction of steam, according to the reaction above, is endothermic, an additional cooling benefit is obtained by using steam in the process. By controlling the rate of steam blown into the converter, the steel temperature is balanced and the need for cooling material in the form of refined alloys or processed scrap is decreased (1kg of steam can typically replace 10kg of scrap in terms of cooling capacity).

Hence the CLU process gives more flexible overall melting, where solid material and steam is optimised to reduce cost and increase productivity. The advantage of improved temperature control and reduced refractory contact time through the use of steam also leads to lower refractory wear.

Strategy

Four process purposes to use steam can be distinguished at Columbus:

– Selective removal of surplus silicon;
– Prolonged lance blowing while substituting argon;
– Substitution of additions and argon when metal cooling is unsuitable; and
– Substitution of inert gases, particularly argon when supply is insufficient or uneconomic.

Fig 2 shows the application of steam blowing in the converter process and how steam blowing and steam consumption is distributed between different steel grades.

The main steam blowing is carried out to prolong lance blowing allowing argon consumption to be lowered. Up to 7kg of steam per tonne of steel is used for low nitrogen ferritic steels. For super-austenitic and periodically for Ti-stabilised steels up to 18kg of steam is consumed per tonne to substitute for cooling additions of scrap and argon, but also to prolong the lance blowing period.

The availability of steam has also saved production during disturbances in deliveries of argon, but this only makes up a small amount of the total steam application. The selective removal of silicon occurs regularly, and corresponds to a small fraction of the total steam used. Nevertheless its impact on the process stability is far more important.

The ratio of production of ferritic steels to austenitic at Columbus in 2007 and 2009 is shown in **Table** 1. It is worth noting the difference between 2007 and 2009. The production of ferritic grades, which constitutes the predominant argon-intensive group, was almost 25% lower during 2009 due to the world economic downturn. Production is expected to

Grade	Ferritic Ratio %		Steam (kg/t)	Total Argon Reduction (%)	MITT Improvement (%)
Year	2007	2009	2009	2007 2009	2007 2009
12% Cr Ferritic grades			6.89	22.4	8.7
17 % Cr Ferritic grades	41	33	2.91	23.9	4.1
Austenitic grades			0.11	26.4	-4.4
Other grades			-	-	-

Table 1 yearly tonnage and process data for Columbus 2007 and 2009

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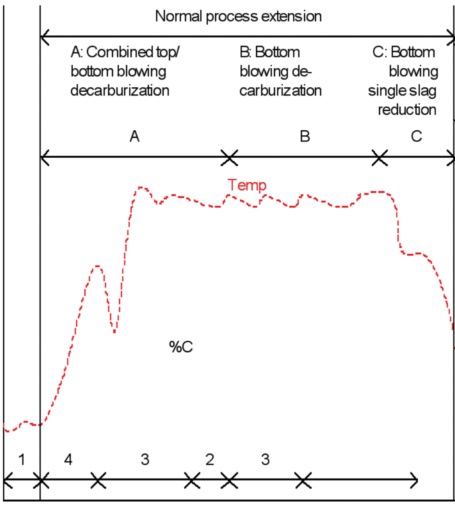
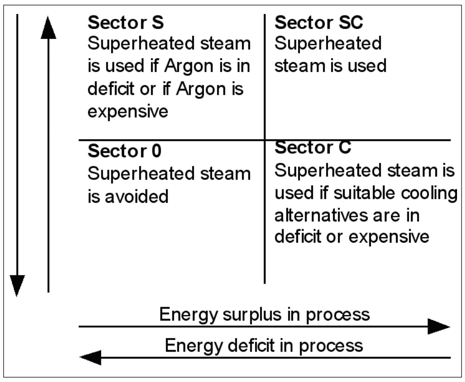


Process purpose	Steam usage kg/ton	Application
1: Steam used for surplus silicon removal	0-1	All grades
2: Steam used to prolong lance blowing while substituting argon	0-9	Ferritic, Super-austenitic and Ti-stabilized
3: Steam used to substitute missing cold additions and argon	0-9	Super-austenitic, high Cr ferritics and Ti-stabilized
4: Steam used to substitute missing argon	0-30	Occasionally on all low nitrogen grades



Above: Fig 3 Business model for steam utilisation decision making

Fig 2 Use of steam in the converter at Columbus

increase once automotive demand picks up. In the Columbus application, steam is used extensively for low nitrogen ferritic grades, as well as high Cr austenitic grades where argon consumption would otherwise be intense.

Results

A total of 20 heats with similar process start conditions were selected for each group of steel grades from 2007 (before reintroduction of steam) and 2009 (after reintroduction of steam). This was to compare process results and analyse possible process benefits since the reintroduction of steam.

The evaluation of process data was focused on argon consumption and process time.

For austenitic grades steam is consumed when high silicon metal is transferred from the chrome smelter. The use of steam in this application makes an important difference because it allows selective initial removal of silicon at low temperature.

Since the reintroduction of steam at Columbus, crude argon consumption has decreased and the steel plant no longer has to schedule production according to argon availability. The results in table 1 show that total argon consumption has decreased by 20-25% for the analysed grades after the introduction of steam.

Improvements in process time were investigated by comparing the Metal In To Tap times (MITT). A decrease in the MITT time is seen for both 12% Cr and 17% ferritic grades with an average decrease of 8.7% on the former. For the austenitic grades, the MITT time increased which is attributed to an increase of transferred charge chrome from the nearby Cr-smelter. The same behaviour would be expected for the ferritic grades but due to the use of steam this was not the case. Accordingly, the additional carbon and silicon load in the process was handled effortlessly by use of steam.

For the high Cr austenitics and low nitrogen Ti-stabilised grades the use of steam had a greater benefit than for the general grades. However, these products only form a small portion of the production mix.

An increase in refractory lifetime of 29% was seen for the period. This could be an effect of improved temperature control due to the steam but this result has to be analysed further. It shows that no negative influence from steam should be expected on refractory performance.

Economic analysis

The benefits of using steam are dependent on the process situation. In **Fig 3** a model to illustrate the usefulness of steam from an economic perspective is presented[4]. The process data from the Columbus case has been analysed by the defined economic model and is discussed below. **Table 2** presents the costs (estimated by UHT) used to calculate the savings of steam usage at Columbus.

Commodity price in Euro					Sector in business model				
1kkg steam	1nm³ N_2	1nm³ Ar	1nm³ 0_2	1t melt in EAF	O	S	C	SC	Comment
0.04	0.03	0.35	0.04	50	0.48	0.08	-0.02	-0.42	Crude argon is substituted
0.04	0.03	0.7	0.04	50	0.48	-0.36	-0.02	-0.86	Pure argon is substituted
0.04	0.03	1	0.04	50	0.48	-0.74	-0.02	-1.24	Pure argon in shortage
0.04	0.01	0.35	0.01	50	0.52	0.10	0.02	-0.40	Compressed air substitutes nitrogen and oxygen
0.08	0.03	0.35	0.04	50	0.52	0.12	0.02	-0.38	More expensive steam
0.04	0.03	0.7	0.04	100	0.98	0.14	-0.02	-0.86	More expensive melting

Table 2 Influence of commodity costs on business model

For argon there is a significant threshold behaviour in terms of price (**Table 2**). This is caused by different prices for crude and pure grade argon along with further price differentiation caused if argon is transported by truck from other sites and if there is alternative use for the argon on other markets willing to pay a high price for it.

The cost for using steam is mainly a function of the argon price and whether melting capacity is being reduced or not. For Columbus the use of steam is motivated when the price of argon is high, when argon is unavailable or when coolants for the converter are unavailable due to logistic disturbances, or if metallic coolants require a sizeable cost premium, such as when used for high Cr austenitic grades where virgin materials have to be used to substitute for scrap.

The savings are mainly made on 12% Cr steel grade coolants when argon availability is too low to enable lengthy campaigns that are necessary from a steel hygiene and yield point of view. On these grades, the threshold behaviour of the argon price becomes evident after a few heats if measures are not taken to avoid its use. On these grades logistics also stop necessary additions of coolants late in the process, so it is logical to put the economic potential in the SC-sector of **Fig 3**.

Before the re-introduction of steam it was common that ferritic campaigns were interrupted due to insufficient argon. This no longer occurs, which improves yield and decreases the necessary stock levels given the same productivity demand.

On grades of super-austenitic steel, steam is applied to both cool the heat and to substitute argon. This has led to important time and argon consumption cuts. Other austenitic grades where steam has successfully been used in significant quantities are the low nitrogen Ti-stabilised grades.

For 2009 the calculated saving by using steam was €0.8M. This is based on the process data using the model and costs presented in **Fig 3** and **Table 2**. The savings will change as a function of the product mix and production tonnage. By using the 2007 production figures the estimated saving would amount to €1.4M.

Significant heat build up takes place in the converters so additional cooling is rarely required during decarburisation. As long as this practice is used it is difficult to discover what the maximum saving potential for steam could be. It is probable that up to twice the consumption of steam could be used based on the product mix in 2007. In that case the total saving potential is about €3M. This would indicate a pay-back time of less than six months for the full investment when the indicated utility costs are applicable. This figure does not take into account strategic benefits, time savings or decreased refractory wear. ■

References

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