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 refractory 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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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).

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:

\[
   \text{H}_2\text{O(g)} \rightarrow \text{H}_2(g) + \frac{1}{2}\text{O}_2(g)
\]

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

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 1.25Nm³ Ar (or N₂) and 0.625Nm³ O₂ 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

\[
   \begin{array}{|c|c|c|c|c|c|}
   \hline
   \text{Grade} & \text{Ferritic Ratio} & \text{Steam (kg/t)} & \text{Total Argon Reduction (kg/t)} & \text{MITT Improvement} \\
   \text{Year} & 2007 & 2009 & 2007 & 2009 \\
   \hline
   \text{12% Cr ferritic grades} & 6.89 & 22.4 & 8.7 \\
   \text{17% Cr ferritic grades} & 41 & 2.91 & 23.9 & 4.1 \\
   \text{Austenitic grades} & 0.11 & 26.4 & 4.4 \\
   \text{Other grades} & - & - & - \\
   \hline
   \end{array}
\]

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

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The benefits of using steam are dependent on economic analysis, which shows that no negative influence from steam has been observed. However, this result has to be analysed further. It is believed that improved temperature control due to the use of steam could be an effect of the production mix.

However, these products only form a small proportion of the total production, and silicon load in the process was handled differently from the Columbus case. Accordingly, the additional carbon charge from the nearby Cr-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 a schedule production according to argon availability. The reduction in table 1 show that total argon consumption has decreased by 20-25% for the analyzed 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 increase of 8.7% for the analyzed 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 use but this result has to be analysed further. It shows that no negative influence from steam is 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. 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.

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 differenti-ation caused if argon is transported from other sites and if there is alternative use for argon on other markets willing to pay a high price for it.

Table 2 Influence of commodity costs on business model

<table>
<thead>
<tr>
<th>Commodity price in Euro</th>
<th>Sector in business model</th>
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<tbody>
<tr>
<td>1kg steam</td>
<td>Nm³</td>
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<tr>
<td>0.04</td>
<td>0.03</td>
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<td>0.04</td>
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The savings are mainly made on 12% Cr steel 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 production 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

1. US Patent 4021233
2. Rick C Columbus Stainless returns to CLU, Nordic steel and mining review, Vol 3/9/0, pg34-35.