

Twinjection™ Technology Improves Hot Metal Desulphurisation at Corus Scunthorpe Works

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Abstract

Powder injection times for hot metal desulphurisation have been dramatically cut by up to 50% at Corus Scunthorpe by the modernisation of the plant using Twinjection™ technology. Twinjection™ technology introduces two powder streams into the hot metal down a single refractory lance. Lower sulphur levels can now be achieved using co-injection of lime and magnesium in a fraction of the previous injection times. This allows Corus to increase the proportion of low sulphur steels that can be made through the plant and makes it possible, should the need arise, to cope with higher incoming hot metal sulphur levels without reducing production rates.

Introduction

The Scunthorpe works of Corus has recently upgraded its hot metal desulphurisation facilities using the Twinjection™ technology of SMS Mevac. Desulphurisation of molten iron was first achieved at Scunthorpe, in 1973, by the injection of calcium carbide (CaC_2) into the torpedoes delivered from the blast furnaces. The efficiency of the process was improved in 1979 when desulphurisation was carried out in the iron transfer ladle, still using CaC_2 . Then, in 1982, the process was further improved by moving to the deep injection of a magnesium based premixed powder, containing approximately 80% magnesium as well as some Al_2O_3 and MgO . The injection of the magnesium powder was achieved by carrying the Mg in a stream of nitrogen gas down a channel in a refractory lance that was inserted into the molten iron with the tip located at about three quarters of the depth of the melt. After a refinement to reduce over injection of the reagent in 1989, the plant served the needs of Corus for hot metal desulphurisation to the present day with a typical injection time of 20 minutes, but with much longer times being required to achieve a final hot metal sulphur level of 0.002% .

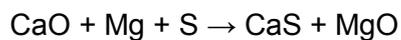
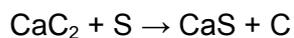
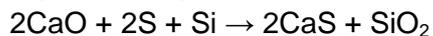
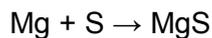
At Corus' Scunthorpe Works, the rated liquid steel production is 4.8 million tonnes per annum (Mtpa), but traditionally output has fallen significantly short of this rated capacity due to the type of products that are being produced at the plant^[1]. The product mix that is produced can significantly affect the tonnage leaving the BOS plant^[2] and as the demand for low sulphur products increases, the desulphurisation process was identified as a potential bottleneck for the plant. The primary reason for investment in the desulphurisation facilities was to give consistent high throughput of hot metal at low final sulphur levels. A further benefit was to achieve a dust emission reduction to the local atmosphere by upgrading the fume extraction system at the same time. SMS Mevac was selected to design, install and commission the modernised desulphurisation facility.

Hot Metal Desulphurisation

It has long been recognised that desulphurisation of liquid iron before the primary steelmaking stage is the most cost effective method to produce low sulphur steels. It can also make the

iron-making stage more economic in that the sulphur limit imposed on blast furnace operations can be more relaxed.

Various reagents have been adopted throughout the world to effect sulphur removal from liquid iron. The most common reagents have included soda ash (Na_2CO_3), calcium carbide (CaC_2), lime (CaO) and magnesium (Mg). These reagents can be used on their own or, more often, in combination. The use of soda ash, as a desulphurising agent, is very much reduced in modern steelmaking due to the decomposition products that were produced in contact with liquid iron and the water soluble slag products that could cause environmental management difficulties. Modern steelmakers now use Na_2CO_3 sparingly, such as in combination with other reagents as a slag flux to help reduce iron losses during deslagging operations at the end of desulphurisation. For the other reagents, the extent of desulphurisation depends on the following reactions:



Deep injection of reagents into liquid iron was developed by injecting a powder of that reagent, with a suitable grain size for conveyance by pneumatic means, near to the bottom of a ladle. Typically an inert gas, usually nitrogen, is used as the transport media for the powder. A refractory coated lance is brought towards the surface of the molten iron and the transport gas flow is established. Prior to entering the liquid iron, the powder flow is established from a fluidised dispenser along a channel inside a refractory coated lance. Once the powder flow is established the lance can then be inserted into the liquid iron and lowered to a pre-defined height in the ladle. Once at the pre-defined height the powder flow rate can be increased to the flow rate appropriate for that powder and a combination of powder and inert gas is injected into the iron. The carrier gas acts as a stirring media as the bubbles expand and rise to the surface. In addition to the active desulphurising reagent, other compounds may be added to aid the stirring of the melt. For the case of CaC_2 , small amounts of volatile additions may be made to improve the reaction rate of the reagent. Magnesium needs no additional stirring agents, since the melting point of Mg (at around 650°C) and the boiling point (at 1107°C) are both below the temperature of liquid iron. In fact, Mg rapidly melts and gasifies, producing a vigorous stirring effect in liquid iron. For this reason the rate at which Mg can be added to liquid iron tends to be limited to between 8 and 12 kg per minute. Once the required amounts of reagent are added, the lance is withdrawn with the reagent still flowing until the lance leaves the surface of the melt. Then the powder flow can be discontinued and the carrier gas turned off when the lance is clear of the melt. After the injection process is finished the slag on the top of the iron will now be rich in sulphur. In order to prevent the sulphur from the slag reverting back into the iron, much of the slag must be removed by raking the slag from the surface of the iron using a steel boom and refractory coated rake. This process is known as de-slagging.

The grain size of the injected reagent must be carefully controlled by the supplier. For a high reaction coefficient the grain size should be as small as possible, to present a large surface area for the chemical reactions to take place. On the other hand, if the grain size is too small, then the material is difficult to convey pneumatically. Each powder will have an optimum grain size distribution that allows its use for deep injection for iron desulphurisation.

Each of the reagents listed above have some drawbacks that should be pointed out. Magnesium powder is obviously highly flammable and magnesium powder for injection into liquid iron is treated with a passive coating to prevent easy oxidation. Lime is easily hydrated, and once hydrated can no longer be conveyed pneumatically and may even set hard in the equipment. Therefore, lime must be kept dry, best achieved by storing under a dry inert gas and kept fluidised. Similarly CaC_2 must be stored under a dry inert gas, with a constant flow of gas percolating through the storage vessel. However, the reason for keeping CaC_2 dry is that it reacts readily with moisture to form acetylene gas, which is highly flammable. Treated correctly, safe storage of the reagents is readily achievable.

Efficiency of Desulphurisation Reagents

The best reagent to use is very much dependent upon both the initial and final sulphur levels anticipated, the temperature of the hot metal and the price and availability of the reagents. The cheapest but least efficient of the reagents is lime. Mono-injection of lime is time consuming and results in large quantities of slag to be removed. Due to the large time requirements for injection and deslagging when using lime temperature losses are the highest for this reagent. It may be used when little desulphurisation is required and a steelmaker has a very low cost lime available. The efficiency of magnesium as a desulphurising agent is strongly dependent on temperature. At lower temperatures the solubility product between magnesium and sulphur is reduced and less magnesium is dissolved in the iron, thus allowing more of the injected magnesium to react with the dissolved sulphur giving a lower final sulphur level ^[3]. Figure 1 shows that at a hot metal temperature of 1250°C, only 0.003% of Mg is dissolved, compared to 0.032% at 1350°C.

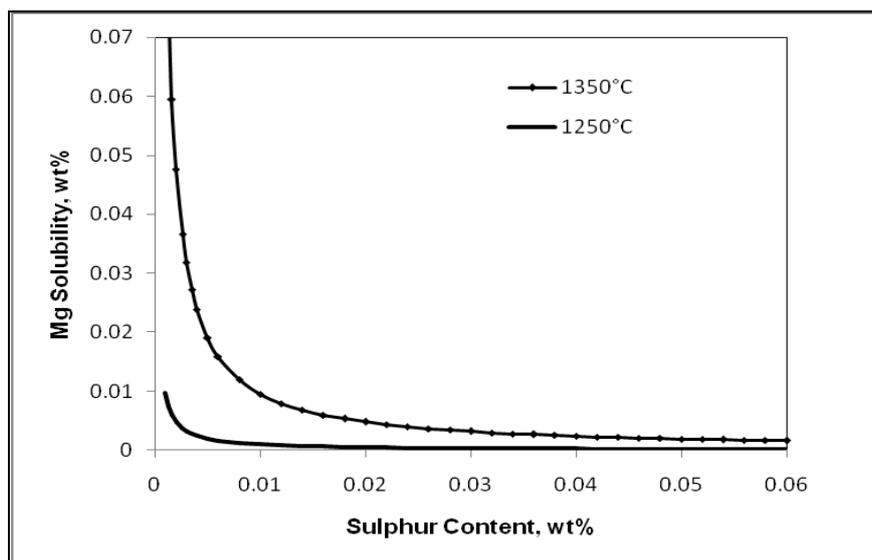


Figure 1. Variation of Mg solubility in liquid iron with sulphur content and iron temperature

When the amounts of Mg and CaC_2 are compared for removal of sulphur at various start sulphur levels, it can be seen that Mg is by far the more efficient reagent by a factor of 10 or more (Figure 2). A cost comparison reveals that despite the higher efficiency of Mg, the high cost of Mg means that per 0.001% of sulphur removed, the costs of the reagents used are much closer. At present, Mg remains a more cost effective option with Mg prices at seven times those of CaC_2 .

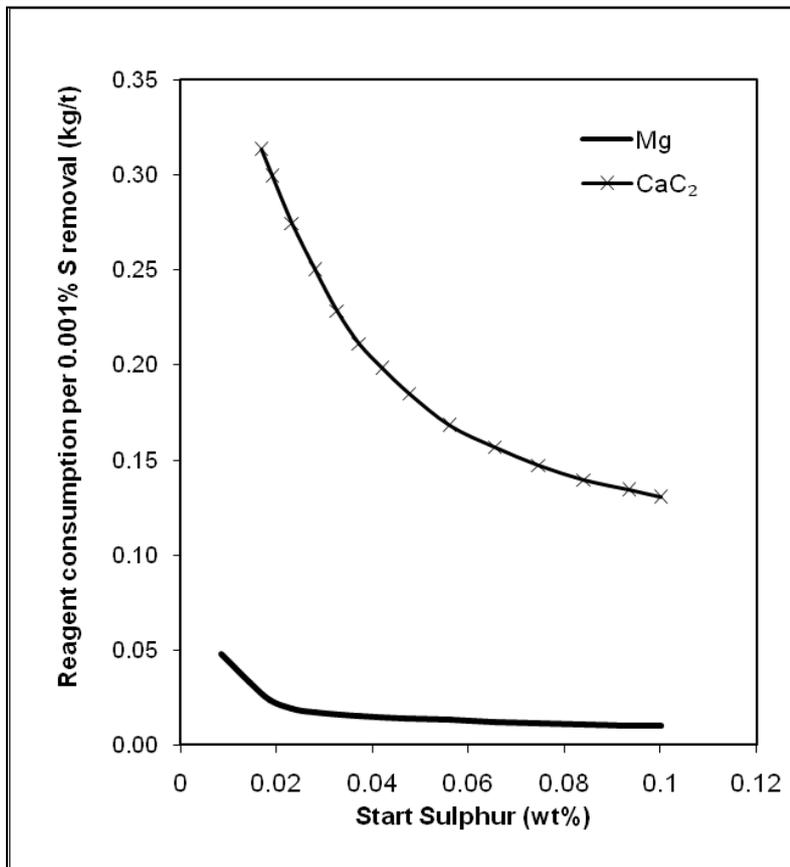


Figure 2. Effectiveness of desulphurisation for lime and calcium carbide for a typical steel plant in 1989

Desulphurisation by Co-injection

The development of co-injection for hot metal desulphurisation in the late 1970s brought reductions in treatment time and large reductions in reagent consumption per tonne of treated metal ^[4]. Co-injection is the simultaneous injection of two or more powders through a single channel. Most commonly, the powders are used in combination with Mg and are usually based on either CaO or CaC₂. Because the powders are controlled independently, the cheaper powder is used to establish powder flow and the more expensive Mg is not added until the lance is in the lowest position in the iron ladle. The main injection period then consists of injection of Mg and another powder and the efficiency of the Mg is improved by fully utilising the Mg for desulphurisation, none is lost by oxidation in the atmosphere. At the end of the co-injection period, CaO or CaC₂ can be continued for a short while to ensure all the Mg is mixed into the steel and fully used. Then the lance can be withdrawn as for mono-injection.

Recent examinations of the sulphur compounds present in desulphurised hot metal and in the slag layer indicate that when Mg is injected with calcium bearing reagents, MgS is readily produced in the liquid metal but only MgO and CaS are detected in the slag ^[5,6]. This is explained by the fact that the free energy of formation of CaS is much lower than that of MgS ^[5], but that the reaction between gaseous Mg and sulphur in the hot metal is much more rapid than the rate of reaction between the solids CaO or CaC₂ and sulphur. This is the reason why co-injection results in much better desulphurisation performance than mono-injection.

Desulphurisation by Twinjection™ Technology

The equipment installed at Scunthorpe offers a two-fold advantage over the previous mono-injection of the magnesium based pre-mix. Twinjection™ offers the improved efficiency of co-injection with the added benefit of doubling the Mg injection rate and therefore a reduction in the injection time. The equipment incorporates two sets of dispensers for co-injection through two separate channels down a single refractory coated lance as shown in Figure 3. Since there are now two separate streams, the vigorous stirring effect from the gasification of Mg can be doubled and the rate of reagent addition is effectively doubled too.

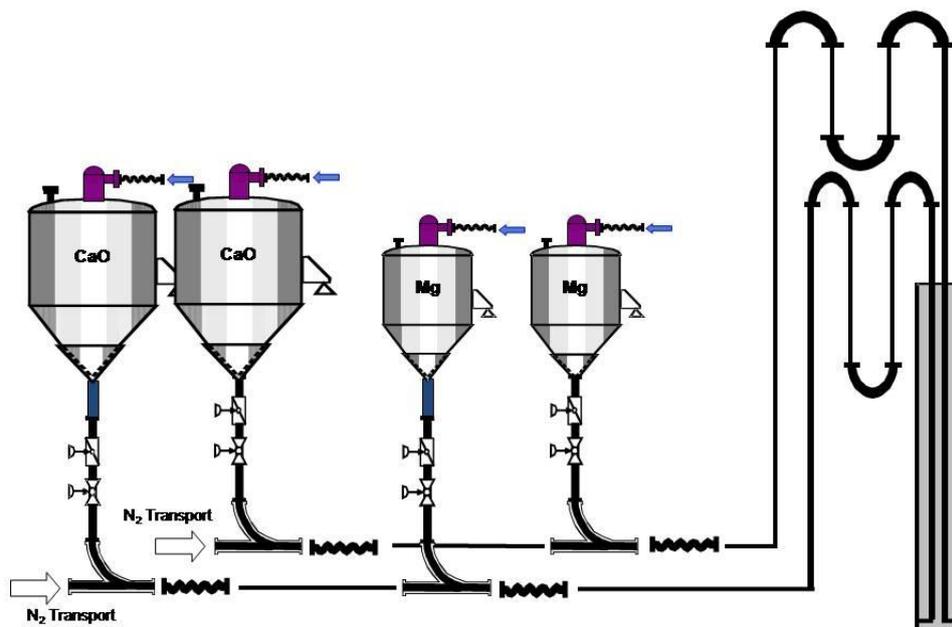


Figure 3 Typical Twinjection™ layout for co-injection of two streams down a single refractory coated lance.

At Corus Scunthorpe, Mg and CaO were selected as the desulphurising reagents. Recent experience at Corus' IJmuiden Works had shown that for their particular combination of iron chemistry and temperature, Mg and CaO injection was a more cost effective option than Mg and CaC_2 ^[7]. The plant was commissioned in August 2008 and using a lime to magnesium injection ratio of 3:1, the consumption of Mg has been significantly reduced for all final sulphur levels. Figure 4 shows how the Twinjection™ plant has reduced the Mg consumption by a factor of more than two, for example, for a starting sulphur level of 0.024%. Similarly for the same data, the total cost of injected reagents has also decreased by more than 50% (figure 5).

The cost benefit of moving to co-injection is very clear from figure 5. However, the significant benefit of Twinjection™ is realised in terms of the reduction in injection time as observed from Figure 6, particularly for low final sulphur levels. Preliminary tests for co-injected lime and magnesium showed that injection times for a final sulphur level of 0.002% were reduced from an average of 28 minutes to an average of 12 minutes. The use of Twinjection™, therefore, allows Corus to increase the number of ladles that can be put through the plant by reducing the cycle time to achieve the same sulphur level. It also allows a greater tonnage of low sulphur grades that can be treated through the plant. Due to the higher throughput capability and lower reagent cost benefit, this gives the plant the flexibility to allow an increase in the sulphur level in the incoming iron or using lower quality (cheaper) scrap with higher residual sulphur levels in the primary steelmaking stage to produce steels of the same final sulphur level.

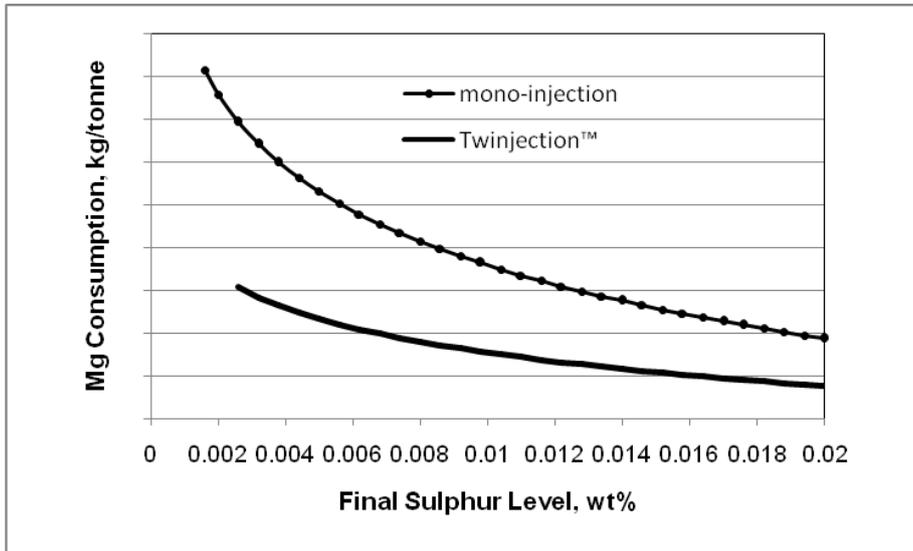


Figure 4. Reagent consumption comparison between former mono-injection equipment and new Twinjection™ co-injection.

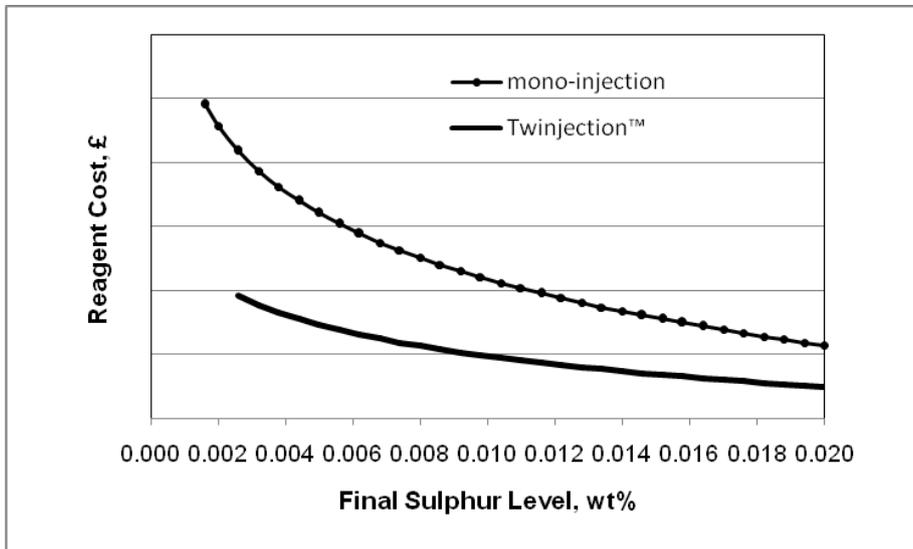


Figure 5. Comparison of the total cost of reagents for desulphurisation from 0.024% start sulphur.

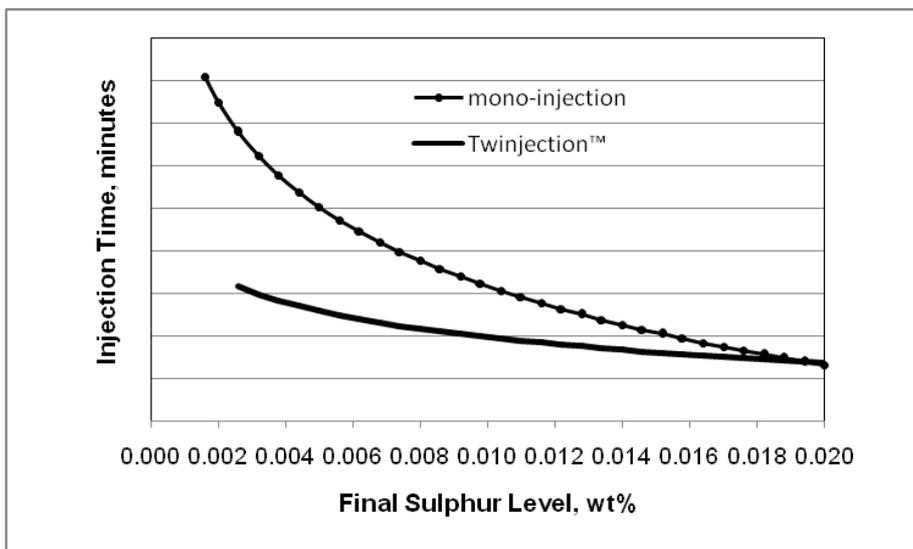


Figure 6. Comparison of injection times for a start sulphur level of 0.024%

Summary

Corus' Scunthorpe Works has upgraded their hot metal desulphurisation equipment from mono-injection of magnesium to a co-injection process using lime and magnesium through the use of the Twinjection™ technology supplied by SMS Mevac. Reagent costs for desulphurisation have been significantly reduced. Injection times have been reduced by more than 50% and the capacity of the hot metal desulphurisation equipment is no longer a bottleneck for the rated capacity of the steel plant. The reduction in injection times achieved now allows the plant to consistently treat 50% more ladles than was the case previously.

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