Development And Application Of A Process Diagnostic System For The Desulphurisation Process

Jamie SHORT[1], Chris BARNES[2], Dr Mark EVANS[1], Paul PRICKETT[3], Dr Roger GROSVENOR[3]

1. College Of Engineering, Swansea University, Swansea, UK
2. Tata Steel Strip Products UK, Port Talbot Works, UK
3. Cardiff School of Engineering, Cardiff University, Cardiff, UK

Abstract: In an increasingly competitive steel industry, with ever-stricter grade requirements for sulphur, the requirement for improved control and efficiency is increasingly important to reduce process costs. This paper describes an online system that has been developed and implemented at Tata Steel Port Talbot Works, to monitor and report on the desulphurisation process. The aim of the system is to generate an objective report on the process, to highlight all process deviations and issues, and facilitate diagnosis. This diagnosis will improve process control and process efficiency. The desulphurisation process typically uses lime and magnesium to facilitate the removal of sulphur from the hot metal and into the slag where this is removed by a rabble. The process, with a start Hot Metal Sulphur of 0.045 (wt.%) and Aim Sulphur of 0.008 (wt.%) typically uses approximately 100kg magnesium and 300kg lime for a 300T ladle. The main focus of this system has been the development of linguistic outputs. The outputs have been optimised to provide concise and interoperable information to assist the operators to quickly understand the current state of the process. The system has been designed to monitor three areas regarding the desulphurisation process; model setup, process deviation and sample availability. A report is generated every morning, for use by shift and plant managers, highlighting every deviation in the process over the past 24 hours and diagnosis of the exact cause where possible. The report is compiled on an exception basis, only highlighting treatments providing there has been an issue or deviation from expected material usage.

An online system has been developed and implemented for the desulphurisation process at Tata Steel Port Talbot Works. The system has been developed to highlight deviations in material use, and process issues, whilst providing diagnosis of cause where possible. The main aim of the system is to provide a summary of all relevant process information, for all treatments, highlighting where a deviation in material use or a process issue has occurred. This facilitates improved control and efficiency of the process, by improving understanding of process state. The system currently compiles a report at 7:30am for the past 24 hours of operation, ready for the morning meetings. Currently this is being developed to provide real time analysis.

1 Model

In Tata Steel Port Talbot works, a computer model is used to calculate the required magnesium (Mg) and lime (CaO) quantities, based on incoming Hot Metal (HM) weight (HMW), temperature (HMT) and sulphur (HMS), and the outgoing Aim Sulphur (Aim S). A model is required, to facilitate the operators in calculating material use, due to the level of variation within incoming process parameters.

This model facilitates a higher level of process control, allowing for a more efficient treatment. The first section of the diagnostic system monitors plant model setup, calculating required Mg and CaO use, for each individual treatment.

The aim of monitoring the model setup is to ensure, based on timings and available analysis, the optimum values are used for the model setup by the operators. This means that material use for each treatment can be well controlled. It also highlights increased planned material use in particular. A simulated plant model has been built into the diagnostic system, allowing all affects on material use to be quantified, from plant model adjustments.

The system has been designed to check for a wide range of different situations, where the model setup has been altered. Given the model parameters available for the operator to adjust, Aim S and HMS are predominantly monitored in this section of the system, along with HMW and HMT.

1.1 Aim Sulphur (Aim S)

The Aim S level is determined by the grade of steel scheduled. Based on the start treatment time the system back calculates the grade of steel scheduled at the time of treatment. This is necessary, as the final steel grade at the end of casting does not necessarily match the grade that was scheduled at the desulphurisation station.

A dynamic scheduling system is used, and reacts to events along the process route, altering the grades accordingly. The back-calculated grade is then used to find the Aim S level for the given treatment and used to compare against the actual value used.

Typically, the main reason for an increase in Aim S is to reduce the time the HM ladle spends in the desulphurisation station. This is done if there is a high level of standage outside of the steel plant when an increased process speed is required. A reduced treatment time will increase the sulphur level in the HM, however this can be compensated for by downstream changes, such as the scrap type used at the Basic Oxygen Steelmaking (BOS) vessel.

There are predefined set Aim S levels for each grade as set by a direct charge limit. These are used as a reference to see if the desulphurisation treatment can be bypassed and the HM charged directly into the BOS vessel. The system checks to see if the Aim S was raised to this value in particular. It will generate an output highlighting the grade being made, the respective direct charge limit and if there has been any change to the scrap mix at the vessel. If however the raise in the Aim S is not to the direct charge limit, the system will generate an output with the format shown in Table 1 event 1.

When the system has highlighted a decrease in the Aim S for a treatment model run, due to this having an adverse effect on material use for the process, the system additionally looks into the scheduling throughout the process for the given ladle. This is necessary, as occasionally the schedule coordinator will alert the desulphurisation stations of grade changes further along the process route, before the coordination plan is updated, to allow them to alter the treatments accordingly.

The system checks to see if this is a possibility, by cross referencing the altered Aim S, with the grade changes and their respective Aim S levels. The system has been designed to check for instances where there is and isn't a match. Particular care has been taken to highlight the most relevant information in all these situations. An example of an output, for a scheduled aim change during a treatment is shown in event 2 in Table 1.

1.2 HM S Adjustments

The second parameter the system monitors is the HMS value used by the operator. The initial processing steps are first to check the availability and secondly the timing of the HM analysis. There are set procedures in place to allow the operators to use estimated values, based on blast furnace runner analysis, if the samples are either received too late for the process or completely unavailable. When this is the case and the estimate has been used no output is generated by the system. This is the correct procedure to take. The system has been designed to highlight however when available HM analysis has been ignored in favour of a higher estimated value.

The system back calculates, based on sample timings and quality, what value should have been used by the operator for HMS. This takes into account unrepresentative and unavailable analysis at the time of the model run. If there is a deviation from this, be it using the estimate over the available analysis or an operator using their own estimate, the system highlights the affect on material use in particular and all applicable timings. An example of the estimated HM analysis being used in favour of the available HM analysis is shown in event 3, Table 1.

2 Process

The primary focus of the process section of the diagnostic system is process performance. This is considered in terms of the number of injections per treatment and material use. This involves monitoring lance issues causing interrupted treatments, over and under treatments, and diagnosing causes of occasional retreatments. Where appropriate these issues are quantified in terms of deviation from the aim end point chemistry, as this is considered a key process indicator.

2.1 Over & Under Treatments

The system has been designed to monitor for over and under treatments. In addition to affecting process cost this can also be an indicator of a process issue. A part of the analysis that takes place when a process deviation has been found is to check for model re-runs during the treatment. This can occur due to late HM analysis for example, where the model is rerun to recalculate required material use based on the newly available analysis. When a treatment deviation has occurred the system generates an output for the given treatment number. This ties in with a model re-run during the treatment. Event 4 in Table 1 shows an example of this type of output. The output contains information on what was adjusted in the new model run, and if any of these have been adjusted to the correct values from initial model setup.

If there has been no model re-runs during uninterrupted treatments, but the heat has still been over or under treated, then this is typically associated with mechanical or electrical engineering issues.

The outputs have been designed to be more detailed for under treated heats in this case, as this will have a detrimental affect on end treatment sulphur levels. In both cases the affect on Mg weight used is highlighted along with the grade number. Event 5 in Table 1 shows an output for an under treated heat. An additional line commenting on the most relevant lab analysis S and its respective aim is added, compared with an over treated output.

2.2 Retreatment Due To Aim Change

As with any batch process, if the end point parameters are not achieved, then the batch can be reworked, or in this case retreated. This happens within the desulphurisation process if the end point S is above the pre-set retreat limit for its given grade. A heat can also be retreated if there has been a schedule change to a different steel grade towards or after the end of the initial treatment, to a lower Aim S than originally treated for.

The system starts by checking if the retreated heat has had a scheduled aim change, between the start of the initial treatment and the end of the retreat that matched the new aim used in the retreat model run. The time frame checked is quite wide. This is necessary as previously mentioned, due to the schedule coordinator occasionally notifying the desulphurisation pulpit in advance of the coordination plan being updated of a schedule change. This allows them to take appropriate action sooner.

The system checks for a number of situations for a retreat with an adjusted Aim S. It checks if a scheduled aim change has occurred. If not the system highlights that manual aims change occurred. It also highlights the respective grade numbers along with Aim S levels. It also notes the timing of the aim change, as this can occur any time between the initial treatment start and the end of the retreatment. An example of a retreated heat with a late schedule change is given in event 6 of Table 1.

2.3 Retreatment Due To High End S

It is also possible if the end point S level has not been reached. This case is particularly important as it implies there is potentially an issue with the process. The system has been designed to systematically work through all plausible situations for this to occur. This includes examining the model setup, including any unavailability of HM analysis before the treatment started, to validating the end point analysis to ensure that the high end point sulphur is plausible.

The system looks into three areas to find the cause of the high end point sulphur: model, treatment and sampling. The model section checks if assumptions made whilst setting up the model were correct. This will reveal for example if the HM analysis was not available or that the estimates used were realistic. The treatment section simply checks to see if the required Mg was actually injected before the treatment was finished and a sample was taken. The sampling section checks the validity of the desulphurisation and hot metal analysis; the desulphurisation analysis is compared against the end blow sulphur level and the hot metal analysis is compared against the Charge Balance Model (CBM) estimates.

Statistical analysis of the CBM estimated S and lab analysis of HMS, showed good correlation between the two values across a large dataset. Thus, if the lab analysis HMS is significantly lower than the CBM estimated HMS and the end treatment S is higher than expected, with no other obvious causes, the system highlights this as a potential cause for the high end S. An example of this output is shown in event 7 of Table 1.

This same approach was used to analyse S pickup from desulphurisation to end of blow. This in turn allows the system to check the validity of the end treatment S analysis, by monitoring the difference between the end of treatment S, minus the expected S removal from the retreatment, plus the S pickup from the scrap mixture used, to the end of blow S level. If this difference is significantly lower than expected, then the end treatment sulphur analysis was either unrepresentative or incorrect.

2.4 Interrupted Treatments

An issue that occurs within the desulphurisation process is interrupted treatments. The timings of these issues within the process are monitored, to allow a diagnosis of the cause to be determined by the system. The system categorises the issues as start, mono and co-injection issues. A start injection issue is categorised as an issue with the lance after the nitrogen flow has been started, but before the lime injection started. A mono injection issue is categorised as an issue with the lance when only the lime has been added to the nitrogen flow. And a co-injection issue is categorised as a lance issue once the lime and Mg have been added to the nitrogen flow.

All interrupted treatments are categorised based on the initial treatment issue. The number of injections during a treatment where issues occurred is highlighted, along with the weight of material injected at the time, in case this highlights a recurring issue. Event 8 of Table 1 shows an example of this output in use.

3 Data Availability

It was considered beneficial to monitor the end treatment sample availability, though only to highlight this when it was statistically significantly low. This is based on the statistical analysis of sample availability over a period of 12 months that has been designed to update every 30 days to account for changes in the process. The system monitors the sample availability over the 24 hour period that it generates the report for, and generates an output if the sampling rate is considered significantly below normal. An example of this is shown in event 9 of Table 1.

Table 1 Outputs From Diagnostic System For A Number Of Events

Event	Treatment	Output
1	73246	61Kg Of Mg Requested, Aim S Raised From [0.005 To 0.015], Grade 3190 Cleaner Scrap Mix Used For This Heat At The Vessel
2	73678	65Kg Of Extra Mg Requested, Aim S Lowered From [0.005 To 0.001], Grade [3046] Aims Change [0.005 To 0.0011], [3046 To 3457] At 08:38 Treatment Finished At 08:46 No Change To Scrap Mix
3	73706	17Kg Of Extra Mg Requested, BF S Estimate Used [0.015], Sample Available [0.011] At 22:45 Treated At 22:55
4	73075	Over Treated By 16Kg Of Mg Compared With Original Model. Model Rerun At 02:36 Using Correct HM S, Treatment Finished At 02:43
5	73092	Under Treated By -12Kg Of Mg Without A Retreat, Grade 3455 No Des S Or EB S, Ladle S Of 0.0049 For Ladle Aim Of 0.006 Achieved, With Correct Scrap
6	69952	Retreat: Due To Aim Change [0.005 To 0.003], [3190 To 4566] At 22:01, Retreat Finished At 22:03
7	73425	Retreat For High End S [0.008] For Aim [0.005] Possibly Incorrect HM S [0.019] As Lower Than BF S Estimate [0.042158]
8	68687	3 Interrupted Treatments, Co-Injection Interrupted At 22Kg Mg, Injected On The South Station
9		Poor Availability Of Desulph S Samples, Measured For 17 Of 35 Heats

4 Conclusions

A diagnostic system has been designed and implemented at Tata Steel’s Port Talbot works to generate a report every morning. This considers the past 24hours of production. The system monitors the model setup by operators, allowing better control of material use for the desulphurisation treatments. The performance of the process is monitored, highlighting interrupted treatments and retreatments. The system supports the diagnosing of possible causes for these. Particular attention is paid throughout to highlight deviations in material use and the effects this has on end point chemistry. This system has allowed a detailed overview of the process to be easily available to all personnel on plant, allowing the state of the process to be better understood, and the control of the process and material usage to improve.

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