Yield and productivity savings using Goodfellow EFSOP™ at MacSteel, Arkansas

EFSOP is a tool used by operators to optimise EAF operation and reduce overall conversion costs. The key components of the system are a patented water-cooled probe, a custom designed continuous gas analyser system and a supervisory control and data acquisition (SCADA) computer. The system has been fitted to two MacSteel EAFs, demonstrating excellent reliability and process control, and generating over $5 per charge ton savings.

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MacSteel's Fort Smith, Arkansas mini-mill produces special bar quality (SBQ) carbon and alloy hot rolled and bright cold finished seam-free steel bar products for the vehicular products market. *Table 1* shows the general equipment at the facility. Through professional association meetings and tours, the EFSOP system was observed and thought to be the control equipment needed to improve refractory consumption, especially delta life. After completing the due diligence, it was realised that there was much more to gain through improved yield and lower usage of consumables. Ultimately, the goal was to improve the efficiency of the existing equipment versus upgrading electrical and/or chemical energy input. For these reasons MacSteel decided to purchase two EFSOP systems for furnaces 3 and 4, with the objectives to reduced EAF operating costs and increase productivity.

The EFSOP system is an off-gas measurement and process optimisation tool that continuously extracts and analyses off-gases from the EAF and uses the real time measurements to dynamically control post combustion within the EAF.

The two systems were commissioned in February 2005 and a number of operational changes were made over a six month period to improve the performance of the EAFs. Closed loop control of post combustion was implemented to dynamically control the burners based on the real time off-gas measurements. Carbon practice changes by melt shop operators also contributed to the performance improvements. At the end of month six the performance improvements included an increase in yield of 1%, an increased in productivity of 1.7% and overall cost savings of over $5 per charge ton.

DESCRIPTION OF THE SYSTEM

EFSOP is a tool used by operators to optimise EAF operation and reduce overall conversion costs. The key components of the system are:

- A patented water-cooled probe
- A custom designed continuous gas analyser system
- A supervisory control and data acquisition (SCADA) computer.

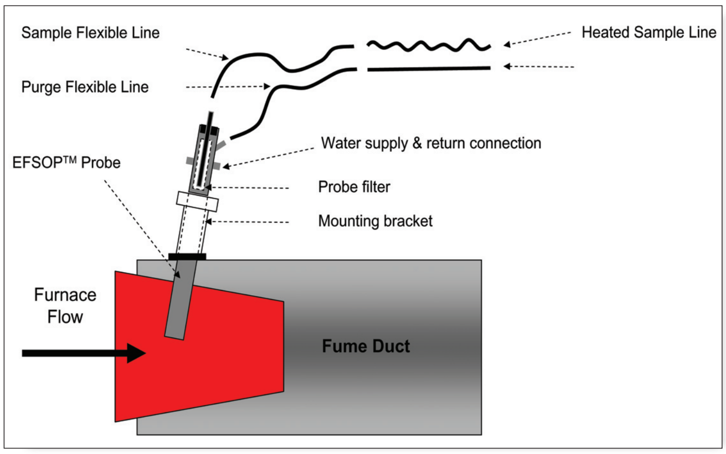

Fig.1 The EFSOP probe at MacSteel Arkansas

Figure 1 shows the water-cooled probe in the EAF at MacSteel. The probe offers extended life in the furnace off-gas and sample filtering capabilities with an internal high temperature filter that removes dust from the sample stream. The barrel of the probe is manually cleaned and the internal filter is changed during the normal maintenance day each week. This takes about 10 to 15 minutes. The probes have lasted over one year to date.

The off-gas sample is drawn by a high volume pump through a combination of hard pipe, flexible stainless steel braided hose and a heated tube to the analyser cabinet. There the off-gas sample is further filtered and conditioned before being analysed for carbon monoxide (CO), carbon dioxide (CO_2), hydrogen (H_2) and oxygen (O_2). The off-gas measurements are converted to 4 to 20 mA signals and sent to the PLC. The sampling system also uses an automatic nitrogen purge system to clean the filters, sample line and probe on a regular basis in order to help ▷

Furnace type	Electromelt
Furnace capacity	61 tapped ton
Charge material	100% scrap
Transformer	37.5/42 MVA
Arc regulation	AMI
Oxy/Fuel injectors	1 Praxair CoJet, 2 American Combustion Inc (ACI) each EAF
Carbon injectors	2 per EAF
Ladle furnace	Demag
Caster	DMS
Vacuum Degasser	Finkl-Mohr
Rolling mill	Birdsboro
Plant capacity	465,000 tpy

Table 1 General Equipment at MacSteel Arkansas Mini Mill

extend the uptime of the system between manual cleaning.

The SCADA computer reads and logs process data from the PLC, performs control calculations and sends process set points back to the PLC. The Human-Machine Interface (HMI), displays the status of the system, furnace off-gas trends and other relevant process information.

INSTALLATION CHALLENGES AND SYSTEM RELIABILITY

One of the major installation challenges was finding a proper location and orientation of the probe where the sample of the off-gas enters the tip of the probe. *Figure 2* shows the unique off-gas exhaust arrangement and various probe arrangements. *Arrangement 1* was first chosen in order to minimise bath radiation into the barrel of the probe by pointing the tip of the probe towards the top line of the roof. Although good furnace off-gas measurements where achieved, the gas exhaust flow had a fairly direct path to inside the barrel of the probe and resulted in premature probe plugging.

The probe was then raised as shown in *arrangement 2*. However, it did not reduce probe plugging and also resulted in inaccurate furnace off-gas measurements as it was diluted with air. *Arrangement 3* was then tried, but the sample was too far outside of the furnace off-gas flow and resulted in measurement of dilution air instead of furnace off-gases. *Arrangement 4* was found to be the optimum solution that achieved low bath radiation, low probe plugging and accurate furnace off-gas measurements.

Another installation challenge due to the unique fume system arrangement required that the sample line be routed on the EAF roof and with the electrode cables. A combination of hard piping on the roof and braided stainless steel flexible lines at the electrode cables resulted in maintenance-free sample line installation.

EFSOP has proven to be a highly reliable system. The reliability for both furnaces is very similar at 97% during a 10 month period from March to December 2005 and the uptime of closed loop control was 94%. Maintenance requirements in order to achieve this high reliability are minimal, requiring only 1 to 2 hours of maintenance per week, which includes cleaning the probe.

OPTIMISATION AND RESULTS

One of the first changes to furnace operation with this system was the implementation of closed loop control (CLC) of post combustion, and the oxy-fuel burners (ACI and the CoJet). For the ACI burners, both the gas and oxygen flow rates are controlled in order to maximise post combustion efficiency. For the CoJet burner, the post combustion oxygen flow rate is controlled. Prior to EFSOP, CLC of post combustion and dynamic control the burners were not possible as there were no other process measurements to feasibly do this.

After observing the off-gas profiles of several heats, it became clear that CLC of post combustion and dynamic control of the burners with EFSOP maximises the use of the burners. *Figure 3* shows the CO off-gas profile of two consecutive heats. Note that the profiles are different, therefore, a fixed standard burner practice for varying off gas profiles cannot be established. Thus the common industry method of a fixed standard burner practice does not maximise the efficiencies and benefits of the burners. The best way to maximise the benefits of burners is dynamic closed loop control using EFSOP off-gas measurements.

Another change to the furnace operation was a reduction of charge and injected carbon consumption by the operators who were responsible for its usage. Once the operators became familiar with the new furnace operation with CLC of the burners, they were able to reduce charge carbon and injected carbon without negatively affecting performance and yield. In fact, the more the operators reduced carbon, the better the operating results became. It appeared that the increased efficiency and energy recovered by the optimisation of post combustion reduced the need for energy from other sources like carbon.

Table 2 shows the results achieved for furnace 3 over four casting cycles during a six month period. First note that a holistic approach to demonstrating savings was taken, incorporating 11 key EAF performance parameters. Also note that only one of the eight reporting periods did not produce savings. The results also show the steady decline in charge carbon usage by the operators from the baseline values of 9.2 to 9.5lb/charge ton to steady values in the last two casting cycles of 5.2 to 5.8lb/charge ton. In general, the overall savings

Performance parameter	Unit	Baseline value -	Performance value - March 12 cycle	Performance value - May 6 cycle	Performance value - June 20 cycle	Performance value - Aug 1 cycle
Primary performance parameters(PPP)						
Electricity consumption	kWhr/ct	384	380	379	386	387
Natural/landfill gas consumption	scf/ct	260	238	221	221	211
Oxygen consumption	scf/ct	721	696	741	762	839
Charged carbon consumption	lb/ct	9.45	9.81	8.47	5.5	5.23
Injected carbon consumption	lb/ct	6.18	5.74	6.00	5.59	5.49
EFSOP PPP conversion cost	$/ct	20.63	20.28	20.16	20.26	20.44
Secondary performance parameters(SPP)						
Electrode consumption	lb/ct	5.96	6.46	6.94	6.45	6.00
Gunning consumption	lb/ct	8.61	9.41	8.74	7.79	8.61
Delta wear	deltas x 1000/ct	0.15	0.12	0.13	0.13	0.13
Refractory wear	$/ct	1.27	0.94	1.02	1.75	1.30
EFSOP SPP conversion cost	$/ct	11.58	12.01	12.62	12.49	11.60
PPP & SPP cost savings		32.21	32.29	32.78	32.74	32.04
Other performance parameters						
Yield	%tls/ct	92.7	93.5	94.1	94.1	93.4
Productivity	ct/POT min	1.239	1.257	1.244	1.257	1.247
EFSOP total cost		32.21	27.75	29.57	27.15	29.39
EFSOP total saving			**4.46**	**2.65**	**5.06**	**2.82**

Table 2 Results for furnace 3

Performance parameter	Unit	Furnace 3 savings	Furnace 4 savings	Overall EFSOP savings	Overall savings %
Primary performance parameters(PPP)					
Electricity consumption	kWhr/ct	-2.7	1.9	-0.4	-0.1
Natural/landfill gas consumption	scf/ct	44	50	47	17
Oxygen consumption	scf/ct	-80	-0.7	-40	-5.6
Charged carbon consumption	lb/ct	4.1	3.5	3.8	41
Injected carbon consumption	lb/ct	0.6	0.4	0.5	8.8
EFSOP PPP conversion cost	$/ct	0.28	0.67	0.47	2.3
Secondary performance parameters(SPP)					
Electrode consumption	lb/ct	-0.27	-0.22	-0.2	-4.0
Gunning consumption	lb/ct	0.41	0.29	0.4	4.1
Delta wear	deltas x 1000/ct	0.02	0.02	0	14
Refractory wear	$/ct	-0.25	-0.26	-0.3	-20
EFSOP SPP conversion cost	$/ct	-0.46	-0.43	-0.45	-3.9
PPP & SPP cost savings		-0.18	0.24	0.03	0.1
Other performance parameters					
Yield	% tls/ct	1.1	0.9	1.0	1.1
Productivity	ct/POT min	0.013	0.028	0.021	1.7
EFSOP total saving		**3.94**	**6.78**	**5.36**	**16.6**

Table 3 Final results for furnace 3, furnace 4 and combined overall savings

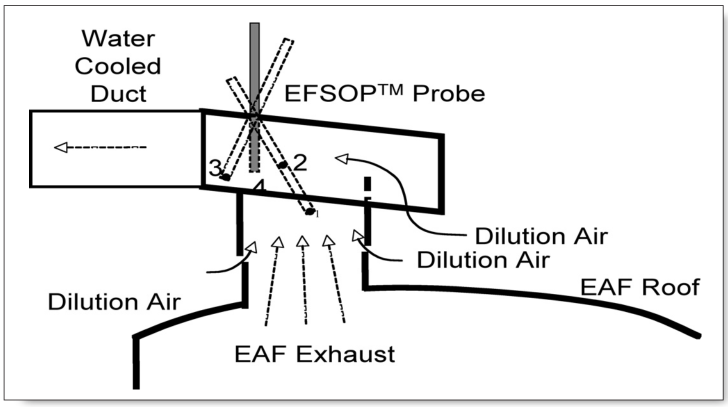

Fig.2 **The probe arrangements**

increased as the amount of input carbon was decreased. The last two casting cycles of June 20 and Aug 1 represent the final savings achieved with the system. Detailed data are also available for furnace 4 which are not shown here.

Table 3 shows the final savings achieved for each furnace and the overall savings achieved based on the last two casting cycles. Note that the results for the two furnaces are different. The total savings for furnace 4 is much higher than furnace 3 ($6.78/charge ton versus $3.94/charge ton) due mostly to a larger increase in productivity. The average of the savings for the two furnaces is over $5/charge ton. The majority of the savings are due to an improvement in yield of 1% and an increase in productivity of 1.7%. These savings have resulted in a nine month payback of the project costs.

The most interesting lesson learned was that significant yield and productivity improvements were possible despite using 17% less gas, 41% less charge carbon and 9% less injected carbon. The belief is that the proper use of gas and oxygen for post combustion under closed loop control conditions increased efficiency and improved energy recovery within the furnace so that less chemical energy from gas and carbon is needed.

SUMMARY

The implementation of Tenova's Goodfellow EFSOP technology at MacSteel Arkansas has been a success. After some challenges to find the proper off-gas sample location, the reliability of the off-gas measurements has been extremely high. The integration of the technology with existing melt shop equipment and operations was fairly smooth. The uptime of the system has also been very high and the maintenance requirements have been low. The furnace burners are now being used to their maximum potential with the use of dynamic real time closed loop control. The EFSOP system has helped to increase yield and productivity. The over $5/charge ton savings achieved has led to a nine month payback of the project costs.

ACKNOWLEDGEMENTS

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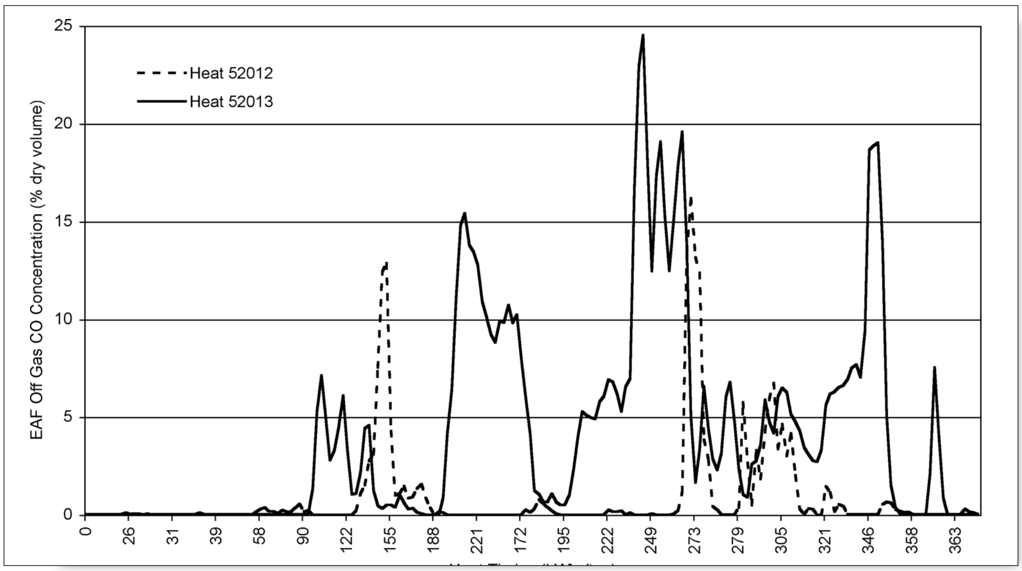

Fig.3 **CO off-gas profiles (March 4, 2005)**

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