LKAB Experimental Blast Furnace (EBF) – A tool for international research

In this issue of MEFOS News LKAB and MEFOS in cooperation present the unique LKAB experimental blast furnace (EBF) and a selection of research activities linked to the EBF project.

In 1996 LKAB decided to build the Experimental Blast Furnace, “the EBF”, and to run the initial five campaigns 1997 to 1999. The main objective then was to develop, test and market a new blast furnace pellet.

At this time there was a strong need for realistic and controlled burden, or pellet, testing on a scale between traditional laboratory test work and production scale blast furnace trials. Laboratory testing is not sufficient to predict blast furnace process behaviour, and production scale trials are risky, costly and often non-conclusive. The target for the design and construction of the EBF was to create a small blast furnace where the burden was subjected to conditions similar enough to full scale furnaces to obtain realistic testing. The furnace has now operated for thirteen campaigns, or over 600 days in total. It has proved to be able to simulate larger furnaces in a relevant way. Various pellets and burden mixes have been tested and evaluated and many other trials and research activities have been performed, by LKAB and MEFOS as well as by others.

Contact:
Peter Sikström (LKAB)
Bror-Erik Sköld (MEFOS)

Key figures of the EBF

- No of tuyeres: 3
- Diameter at tuyere level: 1.2 m
- Working volume: 8.2 m³
- Normal production rate: 35-40 tonnes hot metal/day
- Typical rate of reductants: 500-540 kg/tonne hot metal
- Hot metal: 4.3-4.5 % C, 0.8-1.5 % Si
- Top pressure: Up to 1.5 bar
- Blast temperature: 1200 °C

A cornerstone in our research

LKAB produces iron ore pellets for two major application areas: for use in DR-processes and for iron production via the blast furnace (BF) process. Our BF customers are concentrated in Europe and the decision in 1996 to build the EBF demonstrates a strong commitment to this market. The main target at that time was to develop, test and market new BF pellets and the EBF played an instrumental role in the work to design our most recent pellet grade, the KPBA. Today the EBF is a cornerstone in our research and development work and we have gained unique knowledge from the operation of this small blast furnace, under a wide range of process conditions. The chance to examine samples retrieved during operation or from furnace dissections adds further to our understanding of the blast furnace process. In this sense the EBF has had great impact also on our cooperation with our customers in their various efforts to optimise the blast furnace operation. Our objective today is to use the EBF and the knowledge we have gained to deliver “performance in ironmaking” by adding value to our customers rather than merely providing iron ores.

MEFOS has been our partner in the EBF project from the very start of the pre-study in 1994 and onwards. They were contracted for the design and construction of the plant in 1996-1997 and they still play a major role in the EBF-operation. This partnership has played a great role in the success of the EBF work as our researchers have had the opportunity to concentrate on the trials. The location of the EBF in the steel producing area of Luleå, with its proximity to the university and the infrastructure for pilot plant steelmaking trials at MEFOS has been instrumental in keeping operating costs at an acceptable level. This concentration of metallurgical research in Luleå forms a very creative environment.
SSAB trials with injection of BF flue dust into the EBF

SSAB in cooperation with LKAB has developed technology for injection of blast furnace flue dust. Blast furnace flue dust contains valuable amounts of carbon and iron, and the levels of harmful trap elements are low enough for recycling into the blast furnace. Since 1993, SSAB Tunnplåt in Luleå has recycled the flue dust by charging it into the blast furnace in the form of cold-bonded dust briquette. In the summer of 2000, the recovery of dry dust increased considerably, when the blast furnace and the gas cleaning system were rebuilt. This in turn had a negative influence on the briquette quality and productivity.

A pilot-scale test with injection of BF flue dust into the EBF together with the pulverised coal was performed. Two successful pilot-scale tests were carried out in the EBF. It was found that the flow properties of unground flue dust were superior compared to those of ground dust. During the tests, the amount of reducing agents could be decreased, the BF operation was stable and the silicon content of hot metal was significantly decreased. These test results implied that tuyere injection is a suitable method for the recycling of flue dust. With the good results experienced in the EBF, it was decided to carry out full-scale tests in BF No. 3 at SSAB Luleå Works. When the amount of BF flue dust added to the pulversised coal was controlled, successful results in the processing were achieved. Valuable amounts of carbon and iron contained in the BF flue dust were efficiently used. The full-scale tests showed that BF flue dust is very abrasive and evaluation of the best method for continuous injection and necessary equipment modifications are in progress.

Lena Sundqvist Öqvist and Björn Jansson,
SSAB Tunnplåt AB, Luleå

Contact: Peter Sikström (LKAB)

Rautaruukki trials with high oxygen and oil rates at the EBF

In Rautaruukki, we have a great interest in maximising oil injection and productivity in our blast furnaces. Typical oil and oxygen rates in the blast furnaces are 100 kg oil/tonne hot metal and 26-27% oxygen in the total blast, respectively. Aims and purposes for trials up to 40% oxygen and 200 kg oil/tonnes hot metal were:

- to clarify and to get experimental data on the possible production increase rate with high oxygen/oil rates.
- to define reducing agents’ dependency on the oxygen/oil rates
- to get knowledge about the blast furnace performance, because of bad experience from oil rates higher than 110 kg/tonne hot metal, in our own operation.

In cooperation with LKAB, a total trial period of 4 weeks was performed. The trials were prepared with extensive model calculations to closely define the operation parameters. As a whole the trial period was very successful. The blast furnace reacted in a reasonable way to the increased oxygen/oil rates. The BF operation was steady and process disturbances, when they occurred, were mainly small errors, which were also to be expected with the highest oxygen/oil rates of 41% oxygen and 200 kg oil/tonne hot metal. The ability to reproduce the results was extremely good.

The increase in production was remarkable. Production rate increased by approx. 1% per 1% increase in oxygen percentage in the total blast, when the bosh gas rate was kept constant. When oxygen percentage was raised from 37% to 39% and oil rate was kept constant, the production increase was 1.5% per 1% increase in oxygen enrichment. The total reducing agent rate was constant, independent of oxygen/oil rates. Based on EBF trial results the total economy of operation with high oxygen/oil rates was calculated.

We must stress the important role played by the skilled and enthusiastic operational personnel of LKAB and MEFOS in getting reliable results and low disturbance rate in BF operation.

Kalevi Raipala and Matti Seppänen,
Rautaruukki Steel, Raahen

Contact: Lawrence Hooey (LKAB)
Improved slag formation in the blast furnace by co-injection of basic fluxes, together with pulverised coal, through the tuyeres

In a project financed by Jernkontoret, LKAB and SSAB, MEFOS has developed a technology for injection of BOF slag.

When operating a blast furnace with 100% pellets as ferrous burden, basic fluxes are normally charged together with the pellets. Even if the pellets are fluxed, there is usually a need for basic fluxes to neutralise the acid slag generated in the tuyere area, when coke and coal are combusted. The fluxed pellet itself has an early melting slag, but when it is charged together with basic fluxes, an excessive basic slag can form in the cohesive zone where the top-charged fluxes partly dissolve into the primary pellet slag. The newly formed slag can have a very high melting point and a low fluidity, which can even result in re-solidification of the slag. As a result, the permeability of the cohesive zone and of the bosh region is reduced. Injection of basic fluxes together with pulverised coal, instead of charging them through the top, has been recognised as a possible solution to the problem.

Fundamental research in laboratories at Luleå University of Technology has shown that mixing of pulverised fluxes with ash from coke and coal reduces the melting point of the tuyere slag by more than 200°C. At the same time the slag viscosity is highly improved.

During a two-week period, co-injection of BOF slag and pulverised coal was tested in the EBF. During the trial the ferrous burden consisted of 100% pellets. The objective was to improve slag formation by fluxing the tuyere slag and to avoid an excessive basicity in the lower shaft. All fluxes, e.g. BOF slag, were injected through the tuyeres.

Excellent BF performance was achieved during the trials. The operation was very smooth and stable. The slag volume was around 100 kg per tonne hot metal, and the reductant rate was lowered by 11 kg per tonne hot metal in comparison with the reference period. A significant stabilisation and reduction in hot metal silicon content was reached. Sulphur distribution, as well as output of K₂O by the slag, was improved.

Quenching and excavation of the BF showed that the formation of a birds nest can be avoided when the acid slag, normally generated in the raceway, is fluxed with BOF slag. Injection of fluxes opens up new opportunities to further develop the blast furnace process.

Contact: Jan-Olov Wikström (MEFOS)
European research projects financed by the Research Fund for Coal and Steel (RFCS)

Thanks to the availability of the EBF, MEFOS has been given the opportunity to participate in a number of joint European projects. These projects have been financed by the RFCS, MEFOS’s member companies, Swedish Energy Agency and Vinnova (the Swedish Agency for Innovation Systems).

Investigation of accretion formation in the blast furnace shaft

MEFOS has participated in a project aimed at analysing the mechanism of formation and dislodging of accretions (also called “scaffolds”) in the blast furnace shaft. MEFOS has investigated the formations of accretions in the EBF during three test campaigns. The temperatures of the burden have been evaluated together with process data from the operation. After quenching and dissection of the EBF, this data was compared with mappings of the extension of accretions after each campaign. Samples of the accretions were characterised mainly with chemical analysis, SEM (scanning electron microscopy) and XRD (X-ray diffraction).

The project was finished in 2003 and has resulted in a statistical model which will be tried out on industrial scale later this year. Partners in the project were VDEh, Rautaruukki and CSM.

Contact: Johan Eriksson (MEFOS)

Hearth protection in blast furnace operation by injection of TiO₂-materials

The main objective of the project is to optimise hearth protection by injection of TiO₂-materials through the tuyeres. Blast furnace campaigns can be prolonged by addition of TiO₂-materials, forming TiCN-compounds that protect the hearth walls. In the EBF, injection during the last part of two campaigns is followed by quenching and dissection. The formation of TiCN-compounds in the hearth, as a function of quality of injected material, injected volume and injection position is analysed.

Partners in the project are TKS, BFI, EKO Stahl, VASL, Rautaruukki and CSM.

Contact: Pär Hahlin (MEFOS)

Changes in the microstructure of coke while passing the blast furnace with respect to the quality of the charged coke

In this on-going project the overall objective is to define the optimal coke quality during modern blast furnace operating conditions. During different campaigns in the EBF coke of different quality is tested. Besides the traditional evaluation of blast furnace performance, material is sampled from different positions in the EBF during operation. After quenching and dissection of the EBF at the end of each campaign, sampling is made all through the furnace. Analysis and evaluation is made in co-operation with the partners TKS, DMT, Lucchini, RWTH Aachen, Rautaruukki and CSM.

Contact: Jan-Olov Wikström (MEFOS)

Tuyere stock arrangement at the EBF

Improvement of raceway monitoring under modern blast furnace operating conditions

The function of the raceway presently appears as the limiting factor for the increase of the coal injection rate and reduction of the coke rate. This project aims at investigating the impact of coal injection on the raceway behaviour, and on the corresponding gas distribution within the furnace. The EBF will be used for the direct examination of the characteristics of the raceways obtained for different coal injection rates or coal natures at the time of the dissection of the furnace at the end of the trial campaigns.

Partners in the project are Irsid, RWTH Aachen, CENIM, Aceralia and Aitemin. The project period is 2004-2007.

Contact: Pär Hahlin (MEFOS)
ULCOS New Blast Furnace Process

LKAB and MEFOS will participate in a new RFCS-project aiming at developing a new blast furnace route that should be able to operate with very low CO₂-emissions, based on drastically reduced consumption of carbon containing input materials.

The programme will cover a period of five years, starting July 2004. The most suitable process concept will be defined from mathematical modelling, laboratory tests and technical investigations. The results of that work are basis for tests in the EBF, which will give the first experimentally proven data for the CO₂ reduction potential of the new process as well as process data for technical evaluation.

The basic idea is to operate the blast furnace with cold oxygen instead of hot blast, to make a CO₂-washing of the blast furnace top gas and blow the remaining reducing gas partly through the tuyeres and partly into the lower shaft.

LKAB and MEFOS will lead the two work packages "Design, engineering and modification of the EBF” and "EBF tests”.

In two campaigns, each lasting four weeks, the new blast furnace process will be tested in the modified EBF, in cooperation with European partners.

The RFCS project is co-ordinated by TKS, and 17 partners will take part in the research work.

Contact:
Bror-Erik Sköld (MEFOS)
Jan-Olov Wikström (MEFOS)

The LKAB Experimental Blast Furnace at MEFOS - a useful research tool for the development of future hot metal production

In 1997 LKAB decided to build an Experimental Blast Furnace (EBF) in Luleå. At that time most of the European steelmakers had drastically reduced their blast furnace research activities. Everyone was convinced, that the blast furnace itself was the best practical testing unit. But this proved not to be the case. In the past seven years the productivity of blast furnaces has increased by more than 20 %, while the number of blast furnaces decreased. The necessary permanent availability of the furnaces by improvement in time utilisation on the one hand, and, these days, the necessity for fast switches in raw material adaptations on the other hand make it much more difficult to carry out tests at the blast furnace itself.

This is where the Experimental Blast Furnace comes in. The EBF is a well-equipped furnace with the flexibility for tests of different concepts. The furnace is more aligned to industrial furnaces and delivers more reliable information than laboratory tests, which cannot simulate all internal processes such as gas distribution or alkali and Zn/Pb circuits. This is the reason why TKS co-operates with MEFOS today in the following two European research projects:

- Changes in the microstructure of coke while passing the blast furnace with respect to the quality of the charged coke and behaviour of nut coke in the blast furnace
- Hearth protection in BF operation by injection of TiO₂ materials

Today we can say that the decision of LKAB to build this Experimental Blast Furnace for testing their own pellets and giving the opportunity for joint European research projects to use the small blast furnace as a tool was of a farsighted one, which is something of a rarity these days.

Michael Peters,
Senior Vice President
Hot Metal Production
- Metallurgy/Heavy Plate Division, TKS
Testing of a new burden distribution system

The EBF has been utilised by Z&J Technologies GmbH in the evaluation and testing of a new type of burden distribution system, called the “TopCharger”.

The TopCharger is designed for material charging and distribution inside blast furnaces and other shaft furnaces. The essential features are exact and quick material distribution, but also perfect top gas sealing at high pressure and a very compact design. The TopCharger is a bell-less top system and the figure below shows the lower part of it, where material enters the furnace through a double chute. The chutes are at constant angles and as they can be individually rotated the burden materials can be placed with great accuracy in the shaft.

The pilot scale TopCharger has been in operation in the EBF for two campaigns, or 14 weeks. Very precise distribution of material was accomplished with no material de-mixing. Also, therefore, the gas and heat distribution could be influenced directly and precisely, allowing for improved efficiency and process performance. In a production-scale blast furnace this can facilitate process optimisations and result in improved hot metal quality and decreased coke rate.

Contact: Nicklas Eklund (LKAB)

The TopCharger, a bell-less top system

The most important contract research project in our history

For MEFOS, the EBF-project is probably the most important contract research project in our history. In all different phases, from feasibility study through preliminary design to construction, erection and operation, it has provided an intensive work for us during almost a decade. With the new ideas of nitrogen-free blast-furnace operation in the joint European ULCOS project, in combination with LKAB’s own further raw material development, we can also foresee the EBF being used for many years ahead. We are most thankful to LKAB for putting so much trust in our research institute, and allowing us the possibility to participate in further development of the blast furnace process.

Åke Sjöström, Managing Director, MEFOS

MEFOS announces

SCANMET II

2nd International Conference on Process Development in Iron and Steelmaking

6-9 June 2004, Luleå, Sweden

SCANMET II will focus on research and development activities in steel production, including every step from ironmaking to continuous casting. Major topics include process development, optimisation and simulation of process systems. The conference will also have a broader scope, looking at energy conservation and CO₂ emissions, since the steel industry is a major consumer and producer of energy.

More information on www.scanmet.info

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MEFOS is an independent research institute, established in 1963. Members of the foundation are at present 43 companies and organisations — mainly Nordic steel producers, ferro-alloy producers, non-ferrous metal producers, mining corporations and suppliers to the metallurgical and metalworking industries.

Work is carried out in two well-equipped pilot plants within the fields of process metallurgy, metalworking, energy and environmental technology.