Using Expert Systems in Blast Furnace Operation - a few preliminary impressions

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Abstract

In this paper the enigmatic development of a expert system for blast furnace control in the steel industry. It is used as an example of how a perceived "low tech" industry may develop a "high tech" tool and the paper point to some initial impressions on consequences both on an industry and individual level.

Keywords

Artificial intelligence, Blast Furnace, Control Expert system, Steel Industry

1 THE PARADOX: A HIGH TECH TOOL IN A LOW TECH INDUSTRY

Traditionally, the steel industry is regarded as one of our oldest industries still in operation. Looking at one of the key technologies in the industry, the blast furnace process, it has been known to man for at least six hundred years. However, if a blast furnace on the brink of the twenty-first century is compared to a fourteenth century furnace, how much is really the same? In an abstract sense they are similar, both are charged from the top with iron ore, slag formers and a reducing agents and carbon saturated pig iron is tapped at the bottom. Somewhere here the similarities stop. A modern blast furnace is a highly computerised piece of production equipment capable of producing very large amounts of highly standardised hot metal qualities from different and varying raw materials. Recently,

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the on-going development of the blast furnace process has entered the age of artificial intelligence with the application of expert systems in blast furnace control. Through this introduction, man-machine - and man-to-man - communication has developed and made it possible to further enhance the stability of the process hereby improving operating results of steel producing companies.

1.1 Aim of the study

The introduction of artificial intelligence into the area of iron ore reduction is an apparent paradox: the development and use of a so called "high" tech" tool in an traditional - or "low tech" - industry is - thus - enigmatic.

Accordingly, it is the aim of this paper to relate to a few first impressions of this development and, thus, initiate a discussion on a more reasonable content of the concept of "high technology" and its strategic implications. This paper will also to try to hint at a few possibilities to resolve the high tech - low tech paradox and indicate some experiences from the development such as learning and consequences on an individual careers. The paper uses the genealogy of the expert system tool "Masmester" at SSAB as a starting point.

2 THE BLAST FURNACE AND STRATEGIES TO CONTROL IT

The traditional way of reducing iron ore is the blast furnace process. Contraptions resembling the modern blast furnace has been in use since the 13:th century and the blast furnace - as it looks today - is to a large extent the same as in the beginning of 19:th century¹. However, during this century, the process has gone through major development. The main points are the increase in size of the furnaces and the understanding of the process itself, i.e. what happens inside the furnace during the smelting. The latter has also implied a greater possibility to control the production and the homogeneity of its product, i. e. the hot metal. Part of this development has been carried out in Sweden and the Nordic countries.

The blast furnace operation must be controlled for three main reasons:

- a normal middle-size blast furnace has - roughly - a turnover of 150 MUSD annually, a small per percentage reduction in costs of the blast furnace process may lead to a large reduction in the total cost of a steel producing company.
- smelting in a blast furnace is a slow process; actions by one shift team will linger on to the next
- smelting in a blast furnace is the decisive process in integrated steelmaking (i.e. blast furnace based steelmaking); in the blast furnace in homogeneity the composition of the raw material is equalised, the hot metal is standardised and

¹ Excellent and instructive literature on the blast furnace process is abundant. De usually cited standard account of the process is Biswas (1981) or Peacy & Davenport (1979).

thus the smelting process substantially contributes to the possibilities of the subsequent steelmaking.

Different strategies to control blast furnace operations has been around since the dawn of blast furnace operations. From the beginning the control was carried out by furnace masters (*masmästare* in Swedish). They had extensive experience and new by heart how to operate the furnace by using sights and sounds as the main input data (e.g. Garnej 1791). In a more modern phraseology we would call this *tacit knowledge*. However, this also changed with the twentieth century. By the beginning of the sixties, extensive blast furnace research was carried out (e.g. Edström 1958) and primitive operational models based on thermodynamic knowledge were constructed. The development continued and by the end of the sixties quantitative mathematical models were presented as the final way of operating the furnace and reducing the coke consumption - one of the main engineering problems of the blast furnace.

3 THE GENEALOGY OF THE MASMESTER SYSTEM

3.1 The origin

The development and application of an expert system - Masmester - within SSAB has its origins in the work carried out within the so called "masugnsstyrningsgruppen" (the group for blast furnace control) at the Department of Applied Process Metallurgy at KTH in the mid 1980:s. The work carried out in the later part of the 1980:s resulted in the thesis of Xuegong Bi (1989) and Henrik Saxén (1988).

In the final part of the work, a research engineer from another KTH department - Rutger Gyllenram - worked as a computer expert. In conjunction with the finalising of the project which led to the publication by Bi a possible road to continue the development towards more sophisticated models was discussed. The quantitative models presented hitherto was mainly directed towards modelling the normal condition of the furnace production. Such models were - at the time - relatively well designed but they were found to have little or no application in industry. Blast furnace operators were able to cope with normal operating condition within the limits of the existing information (i. e. when they were not required to take any extraordinary measures). Problems with arose when something out of the ordinary occurred. When such extra-ordinary events happen the relatively simple mathematical relationships which were contained within the quantitative models were not sufficient. Accordingly, such models could not be used as a guiding tool for furnace control.

To resolve this, a plethora of methods was discussed. Gyllenram also undertook a larger survey study to map the state-of-the art of blast furnace control at the time

(Gyllenram 1988). As a result of the study, Gyllenram concluded that (mainly) the Japanese had tried a different approach than mathematical modelling, mainly by using results from the research in artificial intelligent and expert systems.

3.2 Development in academia

Gyllenram turned to Jernkontoret (the of Swedish Steel Producers Association) which is an umbrella under which joined Nordic iron and steel research is decided and supervised (by "committees"). The actual work is carried out either at a steelworks, a research institute or in academia. Gyllenrams suggestion was a loosely formulated project suggestion directed to study the possibilities of using expert systems in Nordic blast furnaces (which were, at the time 7; Fundia Koverhar 1; Rautaruuki Raahe 2; SSAB Luleå 2 and SSAB Oxelösund 2). If this was possible the aim of the study was to create a prototype system for decision making support for blast furnace control. A small grant was approved and the committee, JK 2118/88, was set up to supervise the work. The XPI-project (eXpert system in Process Industries) was carried out was a co-operation between Åbo Akademi, KTH, SSAB, Rautaruuki, Fundia², LKAB and ABB. The XPI-project was started with Gyllenram as a project leader and two young researchers Jacob Sandberg (at KTH) and Leif Karilainen (at Åbo Akademi) was hired two develop the system. As the hardware in the project Digital Vaxstation 2000 work stations were acquired and the main software was the expert system tool Nexpert Object. In the beginning of the project, Sandbergs main problem was to formulate more precisely which parameters was going to be controlled, how this was going to be carried out and how it could be transcribed into an expert system. In conjunction with this formulation, a minor study was carried out (Forsberg and Maurer 1989). Christer Forsberg later continued working on expert systems at ABB. The study was carried out in co-operation with the experienced blast furnace engineer Jan-Olov Wikström at SSAB (later Mefos) and resulted in a draft on how to proceed with decision making support systems for blast furnace control. Wiktröms involvement in the project was essential as he "mentored" the project forthwith. The first out-line, called *Ironmaster*, was very much a result of Wiktröms view of blast furnace control. It was a decision matrix with the possibility to assess the direction of the derivative of the change in temperature and silicon content. If the direction was pointing towards was a too high temperature/silicon content or a too low temperature/silicon content sufficient actions should be made to adjust it, something which e.g. a new shift team could not easily know from the process data they received from the ordinary sources.

² At the time the project began, the Fundia group was not set up but the participating steelworks Koverhar is today part of the Fundia group

3.3 Development in industry

As the co-operation with SSAB began, the project entered a second phase. Sandberg and Gyllenram has access to actual operating data and could more easily identify relevant questions. Hence, the work was directed towards temperature control of the hot metal in the furnace as well as starting and stopping the blast furnace. As a part of this second phase another minor study was carried out at SSAB (Petersohn and Tivelius 1991) which coincided with Sandberg main publication (1992) and exit from the project (he continued as a consultant to SSAB for some time). As Sandberg left the project, the part carried out at academia (KTH and Åbo Akademi) was finished (Karilainen had already left Åbo Akademi for Nokia Mobile Telephones OY in Finland). However, the result, i. e. the prototype, was so promising the SSAB decided to employ Carl Tivelius to continue the development towards a proper decision making support tool for blast furnace control. The industry project, and the support tool was named *Masmester* (from the old furnace masters).

The *Masmester* model was roughly the same as the *Ironmaster* model but with more decision matrices and with a possibility to attach the earlier, more quantitative, models as further decision making support.

4 WHY ARTIFICIAL INTELLIGENCE AND EXPERT SYSTEMS?

Artificial intelligence (AI) and its use has been in the scientific debate for some time now; see e.g. Dreyfus & Dreyfus (1986) or Göranson (1990) for critical discussion of the research. Within AI-research, attempts are being made to model human understanding and thinking to solve practical problem. A few of the results from this line of thinking is the so called neural networks and the expert systems.

Expert system use non quantifiable algorithm and tries, thus, to model the manner in which a skilled person in an area solves new assignments/tasks. Today, expert system only have limited application in industry due to their experimental nature.

5 A FEW IMPRESSIONS OF THE CONSEQUENCES OF THE APPLICATION OF MASMESTER AND ITS GENEALOGY

5.1 Off line work and learning

When the improved Masmester model was tested in operations (including the older quantitative models) there were big difficulties in system stability and "intercomputer communication". It was also an experience that text based interfaces was not enough base for the operators to act upon. The operators also found that the blast furnace management did not demand the types of reports presented by the system. Accordingly, the operators did not find it interesting to improve and make

operational a system which was not demanded by there superiors. However, it was the Rautaruuki experience that the implementation of an off-line expert system enhanced the skills operators who earlier tended to act rather at the "too late/too little principle". In the SSAB case, such experiences were limited (Tivelius 1994).

In the middle of the 90:th it was generally considered that the expert system technology was coming of age even though the Masmester project had come to a halt. One of the initial finish participants in the project, Rautaruuki had, e.g., bought a Japanese system for control decision support (Kawasaki).

5.2 Individual careers

There is also an individual aspect to this development. Several of the involved in the project has continued to work with expert systems and computer development. As mentioned Christer Forsberg work on expert systems at ABB, his college and the ABB representative on the original committee JK 2118/88 Lars Hultin has moved to Microsoft and Carl Tivelius to the business system provider Intenia. Accordingly, the traditional industry has provided the growing with competence.

6 RESOLVING THE HIGH TECH - LOW TECH PARADOX

At conference the well known philosopher Stephen Toulmin once remarked "we do not only live in the age of high technology, we also live in the age of low economics". What he was referring to was the fact that mass production has provided us with the possibilities of a luxury hitherto unknown to man. Let us, e.g. take a simple and common object as a chair. In a reconstruction of the wooden chair of king Tut in Egypt, the master craftsman Thomas Tempte (1988) experienced fundamental difficulties in creating a - perceived - simple thing as a chair without modern tool and without the experiences know to the ancient master craftsmen (cp. the old furnace masters above). Accordingly, high tech and low tech is very much in eye of the beholden and not necessarily something inherent in the product. I may, very well, also be inherent in production process. Since "high tech" is a catch word in the political debate today it is necessary to address the simplistic view that "high tech" equals high production value or the demand for more competent employees, cp. e.g. manual assembly of computers which, in statistic may show up as valuable export. The "low tech" image of the steel industry has strategic implication as it has been perceived as a problem. The industry has experienced difficulties in relating its problems and possibilities to the public in general and, more specifically politicians and - perhaps a major strategic point - to recruit well educated and competent young co-workers. The development of a unique control system in an industry in which the main technology (the blast furnace) has almost ante-deluvian ancestry may be one way of resolving a high tech/low tech paradox.

7 FINAL COMMENTS

The point is not whether Masmaster itself was a successful development or not but the fact that resources was allocated to such a risky and "high tech" venture in a low tech industry. If this had been carried out within the framework of a company in the information technology industry it would have easier to comprehend, fund and get support from the above mentioned groups. Thus, what is perceived as an ancient technology does, with a closer inspection, show a remarkable adaptability to modern technology and may, if the focus is slightly modified, be truly labelled as *high technology*.

8 INFORMANTS

Interviews and discussions were mainly carried out during the years 1990 - 1995 but the material has been updated recently. The following informants participated in the study: at KTH: Rutger Gyllenram, Jacob Sandberg, at Åbo Akademi: Henrik Saxén, at Rautaruuki: Kalevi Raipala, at ABB Christer Forsberg, Lars Hultin, at SSAB Jan-Olof Wikström, Carl Tivelius. There participation is greatly appreciated.

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10 BIOGRAPHY

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