PROCEEDINGS : CAMME-1996
©NML JAMSHEDPUR; pp.37-47

Computer applications in steel industry

SANAK MISHRA, A.K. SANTRA and V.K. GUPTA

*Research & Development Centre for Iron & Steel,
Steel Authority of India Ltd., Ranchi - 834 002, India*

ABSTRACT

An overview of the current status of computer applications in the steel industry has been presented from the point of view of process automation and control. Specific areas covered range from sintering to rolling - including energy and transport management. It has been concluded that development of more intelligent man - machine interface for computer aided analysis, simulation and implementation of control system coupled with advances in software engineering, parallel processing, high performance graphics and artificial intelligence based systems have led to considerable advancement in all areas as evidenced by significant improvement in both the plant productivity and product quality, the world over. Efforts being made in India in general and at R&D Centre of SAIL in particular have been highlighted. In this context, generation of our own technology and a rational and intelligent selection and adoption of various technical advances has been emphasised.

INTRODUCTION

In the plant environment, computers perform a number of functions. Typically these include data collection, data storage, data retrieval, report generation, number crunching, off-line scientific calculations, conventional control, and implementation of optimizing control. During the last three decades or so, use of the decision-making capabilities of a computer together with its flexibility in developing control loops and strategies has resulted in significant improvement in both the plant productivity and product quality, in all types of industries the world over. Steel industry is no exception. In fact, Williams[1,2] has stated that the most extensive and most successful applications of plant-wide, integrated computer control systems have been in the steel industry[3-8]. It should also be pointed out that in almost all these cases, the installed computer systems have shown payouts in fractions of a year[3,7].

Over the last two decades, the computer technology itself has undergone revolutionary changes. Cost and physical size have gone down, storage capacity, computing ability as well as reliability have increased by leaps and bounds. Moreover, it has become possible to design and support very user-friendly softwares through the use of graphical user-interface. This coupled with global competition in respect of product quality and cost has spurred the use of computers in process control as well as production planning and control. No plant is viable today without extensive computer based process control as well as production planning and control.

A hierarchical arrangement of various production tasks is shown in Fig. 1. At the lowest level, drives and closed-loop controls work directly in conjunction with the respective machines and units. A group of open and closed-loop controls automates a complex unit, e.g. a roughing mill, and is assigned for this purpose to a process control system. The production control system monitors and controls a complete production area consisting of several process control systems. At the top of the pyramid is a management and planning computer for processing mainly commercial tasks.

This paper gives an overview of the different types of computer applications in various areas of the steel industry.

CURRENT STATUS

Transportation Problems

In steel plants, ore transfer from ore yards to the ore bins by conveyor networks is a very complex operation. For example, in Kakogawa Works of Kobe Steel Ltd. this operation involves more than sixty kinds of ore, more than four hundred conveyors and more than one hundred ore bins. Morita *et.al.*[10] developed an on-line integrated computer control system for carrying out this scheduling job. The problem was solved using combinatorial mathematics and linear programming. Another interesting example pertains to detailed planning and scheduling starting from steel making through secondary metallurgy, continuous casting to hot rolling. Melt Shop Manager is a highly configuarable software module developed by the Broner Group Ltd.[11] for this purpose. It can meet varying requirements of different steel plants. It balances the competing demands of productivity, costs, delivery performance, slab stocks and hot charging against the technical constraints of the process. This module operates at three levels:

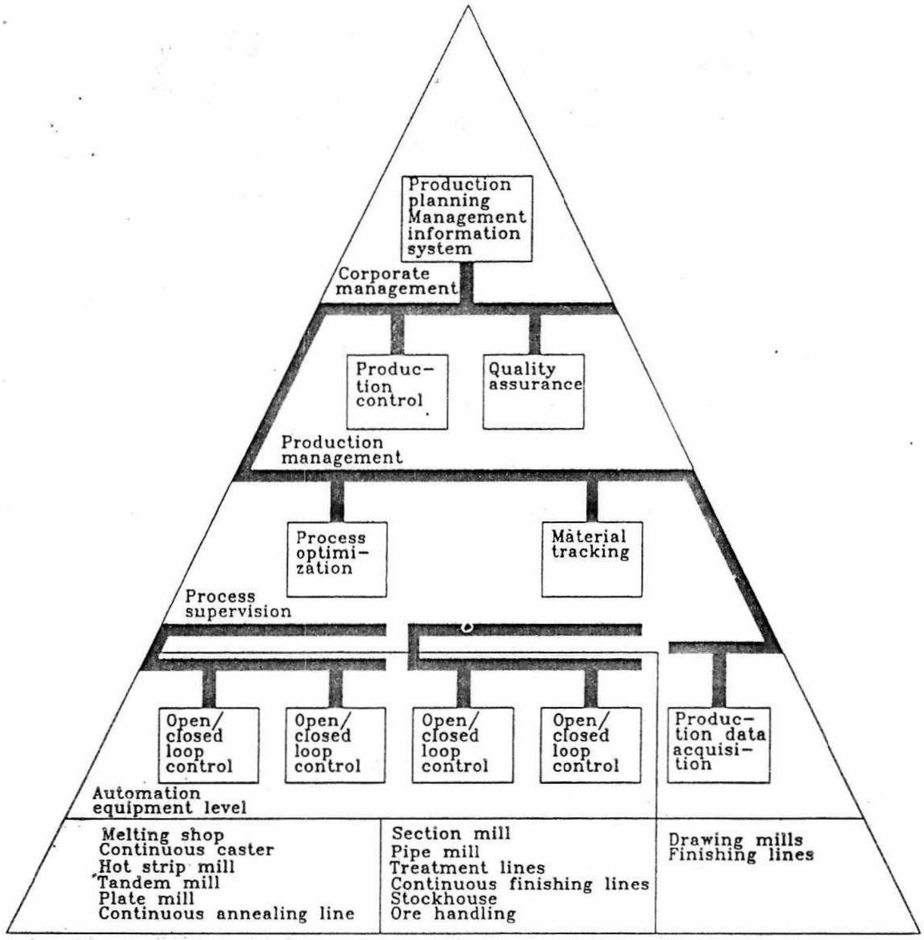

Fig. 1 : A hierarchical arrangement of various production tasks.

(i) medium term planning, (ii) short term scheduling and (iii) on-line coordination.

Sintering

In the area of sinter production, Sumitomo Metal Industries Ltd. developed a Direct Digital Control (DDC) System which performs a series of process controls, from the raw materials weighing to the burn through point control[12]. Use of this system resulted in significant reductions in the coke ratio and variations in RDI and basicity. Another interesting example is the automation of sintering plant at Bhilai Steel Plant[13]. The APACS system is used for data acquisition. A PC is used for implementing proportioning control. Control strategies used ranged from adaptive control to fuzzy logic.

Blast Furnace

Blast Furnace operation has been the subject of a large number of computer application efforts[14-18]. Christiansen[14] developed a very comprehensive dynamic simulation model to predict flow rates, compositions and temperatures of the top gas, slag, and hot metal exit streams as a function of time from specification of the time - dependent tuyere inputs and raw material charges. The model showed excellent ability to follow eight days of time-dependent operating data for an industrial furnace. The model is ideal for development of optimisation and control strategies. Similar efforts were noted in the work of Cross et. al.[15], who dealt in particular with the effects of changes in burden distribution on cohesive zone shape and top gas profile.

Pesonen and Saarelainen[16] have dealt with blast furnace process control at Ovako-Koverhar in Finland. At this plant an on-line computer based process control system was commissioned as early as 1980. The system was based on a number of simulation models. These included models for shaft, tuyeres zone and hearth, a thermodynamic model and a model for gas distribution interpretation. It was concluded that supervisory control is an efficient way of managing the complex blast furnace process as it helped achieving reduction in coke rate and increase in productivity.

A new concept is the development of Expert Systems. The Expert System combines the knowledge and expertise of the process operators and engineers with process models and can be designed to cope with incomplete and/or incorrect information. These softwares emulate the decision making abilities of a human being. Introduction of an on-line realtime expert system at B.F. No. 5 of Fukuyama Works of NKK in 1986 was another remarkable achievement in the area of computer applications[17]. The system consisted of two sub-systems: 'Abnormal Furnace Condition Prediction System' and 'Furnace Heat Monitoring and Control System'. The system could predict the occurrence of burden slip, channelling and unstable conditions with good accuracy. Rautarukki's blast furnace supervision system is another significant development[18]. It is designed to support the decision-making in medium and long-term process control and to have an easy access to the current state of the process. An expert system has also been developed by them. It has been found to be a reliable tool in the control of the furnace state.

Steel Making/Continuous Casting

Use of Artificial Neural Network (ANN) models is an interesting development. ANN is a technique used to develop a model based on process information or its input-output behaviour. Chakraborty *et.al.*[19] have developed a neural network based mould breakout detection system for a continuous caster. Kumar *et. al.*[20] have developed an expert system for trouble shooting quality problems in continuously cast products. Sasabe[21], Kominami[22], Lock Lee[23] and Kumar[24] have also developed expert system for various aspects of continuous casting operation. Miki[25] has described computer control for continuous casting at Kobe Steel Ltd. Significant improvement in casting efficiency could be achieved. Mannesmann Demag has developed and successfully implemented a sophisticated process model for BOF converters[26].

Rolling

In the area of rolling, hot strip mills have perhaps received the maximum attention. NKK developed a continuous process digital simulator based on a new tension control method[27]. It involved application of looper control technique under modern control theory. A 40% reduction in the longitudinal thickness variation of the strip could be achieved at Keihin Works. At Hirohata Works of Nippon Steel Corporation an absolute mode Automatic Gauge Control (AGC) system was developed to achieve extremely high accuracy in thickness control[28]. The system consisted of four main subsystems organically combined, and it involved use of several advanced techniques such as non-interferization between thickness and shape, and the looper control of optimum regulator type. Another interesting example is the development of a Camber Control System for rolling of plates at Mizushima Works of Kawasaki Steel Corporation[29]. Boucher and Fromont[30] have described a microprocessor based rolling mill digital speed control. Automation of a tandem cold rolling mill has been discussed by ter Matt[31] and that of Sendzimir mill by Kawaguchi *et. al.*[32]. An advanced control system for bar rod and wire rod mills of Bhilai Steel Plant has been developed by ABB Bangalore[33]. The control system is based on microcomputer based technology and includes fast and accurate digital speed control, a mill cascade system for distributing control system, low tension control and loop control. Use of the system has resulted in reduction in defects and increased availability of the mill. MARAS is another powerful application software for rolling mills developed by the Broner Group Ltd.[11]. Finally, mention should be made of a neural network based control scheme developed recently at Krupp Hoesch Stahl for obtaining more precise presetting of a wide-strip mill[34]. Excellent results have been obtained using this system.

Energy Management

Considerable amount of work has been done on control of furnaces and energy management in general. Geskin[35] has discussed automatic control for energy saving in heating furnaces based on maximum principle, linear and dynamic programming. Doi *et. al.*[36] have described a computer control system of the reheating furnace for continuous cast bloom at Kobe Works of Kobe Steel Ltd. An optimal heating pattern is determined by on-line calculation in order to minimise the total fuel consumption using linear programming method. Fuel consumption could be reduced by 10%. Nose *et. al.*[37] have discussed a systems engineering approach to the optimisation of hot blast stoves. Prasad Rao[38] has described the experience of using state-of-art instrumentation and on-line mathematical model for heating control of BF 6 at Bhilai Steel Plant.

STATUS IN INDIA

As the demand for reliable steel products of high quality, at competitive cost, has assumed centre-stage in the market place, computerisation and automation are being increasingly adopted by steel industry in India. The current status of computerisation in India is summarised in Table 1.

Efforts at SAIL R&D Centre

For the last ten years or so, the R&D Centre of SAIL at Ranchi has pursued a number of computer application projects in several areas.

For iron ore mines, a PC based excavation planning system was developed with a view to reducing day-to-day fluctuations in the iron ore quality in respect of Fe content and Al_2O_3/SiO_2 ratio[39-41]. Given the location of the shovels, chemical composition of the ore at each shovel site, number of dumpers available, and the desired production level, the optimum schedule of dumpers could be obtained. It was demonstrated that the magnitude of fluctuations in the ore quality could be brought down by about 50%.

Table 1: Level of Computerisation in India

No.	Area	Status
1.	Plant wide network	Implemented at TISCO and being implemented at Durgapur Steel Plant.
2.	On-line production	Being implemented at Durgapur Steel Plant, Vizag Steel Plant and TISCO
3.	On-line inventory control	Implemented at most steel plants.
4.	Maintenance management	Implemented at most steel plants.
5.	Traffic management system	Implemented at Bokaro Steel Plant and Bhilai Steel Plant.
6.	Process control in RMSBY	Being implemented at Durgapur Steel Plant and Rourkela Steel Plant; Data acquisition system implemented at Vizag Steel Plant for ore and flux
7.	Process control in Coke Ovens	Implemented at Bokaro Steel Plant and Bhilai Steel Plant.
8.	Process control in Sinter Plant	Implemented at Bokaro Steel Plant and being implemented at Durgapur Steel Plant and Bhilai in Coke Ovens Steel Plant.
9.	Process control in Blast Furnaces	Implemented at Bokaro Steel Plant, Bhilai Steel Plant, Durgapur Steel Plant and being implemented at Rourkela Steel Plant.
10.	Process control in BOF	Implemented at Vizag Steel Plant, Bhilai Steel Plant, Rourkela Steel Plant, Durgapur Steel Plant and TISCO
11.	Process control in continuous casting shop	Being implemented at RSP, Bokaro Steel Plant and TISCO
12.	Soaking Pit process control	Implemented at Bokaro Steel Plant and Rourkela Steel Plant.
13.	Reheating Furnace process control	Implemented at Rourkela Steel Plant. Being implemented at Bokaro Steel Plant.

With a view to control the performance of the iron ore crushing circuits at the mines, a computer simulator was developed using well established mathematical models of crushers and screens and extensive plant operating data[42,44]. The simulator was used to establish the optimum values of important parameters such as the ore feed rate, crusher gap setting, screen angle of inclination and screen aperture for different ore types (hardness) and feed size distributions.

A PC based Decision Support System (DSS) was developed for the coal handling plant of Bokaro Steel Plant[45]. The plant received coal from more than six different mines. These coals were stored in forty-six different silos and were transported to the crushers through three conveyors. The optimum coal withdrawal schedule is predicted by the DSS such that under the given conditions, there is only minimum possible deviation from the target coal blend quality. It was demonstrated that a considerable improvement in the coal blend quality could be achieved.

For control of hardness of steel strips in the Hot Strip Mill, a mathematical model based software was developed[46] to obtain the number and sequence of cooling banks/headers on the run-out-table (ROT). It required developing a description of the thermal profiles and phase transformation taking place during the cooling of the strip as a function of the cooling conditions for a strip of given chemical composition and thickness. Implementation of model predicted cooling conditions at Rourkela Steel Plant resulted in significantly lower average hardness values for coils of various gauges.

Refinement of raw data gathered in the plant environment from the material balance point of view has been another important area of interest. A software package RORDAT has been developed for multiple input-multiple output single process units[47,48]. It ensures minimum possible overall adjustment in all the assay and flow rate data as per the relative reliability of each measurement. When data are redundant, it is possible to predict, to a fairly good degree of accuracy, even those parameters which cannot be measured in the plant environment. Such refinement of raw data is a must for carrying out any meaningful evaluation and analysis of the process. This software has been used for blast furnaces of Durgapur and Bhilai Steel Plants.

In the context of controlled rolling of microalloyed steel at the plate mill of Bhilai Steel Plant, a computer based mathematical model was developed for determining a safe and optimum draft schedule[49]. This model is based on Amatsky method, and it takes into account the grade of steel, rolling temperature, roll diameter and input thickness of the slab/plate. It predicts the roll separation force and moment of rolling. Model tuning and validation was done for production of API X-56 grade plates.

CONCLUSION

During the last two decades, the number of technological advances and the speed of diffusion of their applications has been enormous by all standards. Micro-computers, which appeared in the market in 1974, have probably been the main force behind this rapid and accelerated development. Real time digital control systems can be considered as the basis of a new industrial revolution which is already with us. New developments in Artificial Intelligence such as the Expert Systems and Artificial Neural Network models coupled with rapidly increasing power and falling price of computing hardware, and the vigorous research activity in software engineering, parallel processing and high performance graphics are opening up a window of opportunity for the control engineering community. As outlined by Barker[50], development of more intelligent man-machine interface for computer aided analysis, simulation and implementation of control systems, supported through a menu driven, high resolution colour graphics workstation environment with both local and networked computing resources will further improve the capabilities of the process control engineers.

In the Indian context, it should be emphasised that it is important to generate our own technology simultaneously and not import various technological gadgets indiscriminately. A rational and intelligent selection and adoption of various technical advances will ensure continued success.

REFERENES

[1] Williams T.J., *IFAC Proc. Series,* 12, 1988, pp187.

[2] Williams T.J., *Computers in Mech. Engg.,* 2-4, 1984, pp14.

[3] Gochi E. *et.al., The Sumitomo Search,* 24 (November 1980).

[4] Wick H.G., *Iron and Steel Engineer,* 59, 1982, pp56.

[5] Miyake J. *et.al., Nippon Kokan Tehnical Report,* 28, 1980.

[6] Kramer S., *Automation of Information Systems, Estel Hoogovens B.V.,* Ijmuiden, The Netherlands, July 1981.

[7] Anonymous, Strategic Plan, Overall Computer Control, Gary Works, *U.S. Steel Corporation,* Gary, Indiana, 1980.

[8] Systems Engineering Group, INCOS Project, *Tasks and Functional Specifications of the Bhilai Steel Plant Integrated Control System (INCOS),* Steel Authority of India Ltd. Delhi, India, April 1986.

[9] More Cost-Effective Manufacturing Using Production Control *Systems in the Basic Industries - A publication of Siemens AG.*

[10] Morita T., *et.al., Proc. 3rd IFAC Symposium,* Montreal, August 1980,

pp53.

[11] *STATUS,* A publication of the Broner Group ltd., Watford, Herts, England, Summer 1996.

[12] Arai O., *et.al.,* Proc. *4th IFAC Symposium Helsinki,* August 1983, pp347.

[13] Khurana H., Tiwari, B.B. and Krishnan N., *Proc. National Convention on computerisation and automation in steel industry,* Ranchi, February 1996, pp13.

[14] Christiansen E.L., *et.al., Proc. control'84 (Mineral/Metallurgical Processing),* SME/AIME, New York, 1984, pp337.

[15] Cross M., *et.al.,* ibid, pp347.

[16] Pesonen I., and Saarelainen E. 4th IFAC Symposium Helsinki, August 1983, pp387.

[17] Shibata M., Hashimoto K and Wakimoto K., *4th IFAC 10th Triennial World Congress,* Munich, FRG, Vol. 6, July 1987, pp287.

[18] Inkalay P. and Rasanen J. *Proc. National Convention on Computerisation and Automation in Steel Industry, Computer Society of India,* Ranchi, 1996, pp142.

[19] Chakraborty S., Bhaduri R. and Prasanna Kumar, T.S. *ibid,* pp152.

[20] Kumar A., Mishra N.C. and Singhal L.K., *ibid,* pp163.

[21] Sasabe Y. *et.al., ISIJ International,* 30-2, Feb. 1990, pp136.

[21] Kominami H. *et.al., Nippon Steel Technical Report No. 49,* April 1991, pp34.

[23] Lock Lee L.G., *ISIJ International,* 30-2, Feb. 1990, p.90.

[24] Kumar S. *et.al., Iron and Steel Maker,* Sept. 1993, pp29.

[25] Miki K., *4th IFAC Symposium Helsinki,* August 1983, pp281.

[26] Schramm R. and Klingenberg R., *Proc. National Convention on Computerisation and Automation in Steel Industry,* Computer Society of India, Ranchi, 1996, pp24.

[27] Hayashi Y *et.al.,* Proc. *IFAC 10th Triennial World Congress,* Munich, FRG, Vol. 2, 1987, pp101.

[28] Tsuji Y., *Ibid,* pp107.

[29] Tanaka Y., *et.al., Ibid,* pp147.

[30] Boucher P and Fromont J., *Proc. 3rd IFAC Symposium, Montreal,* August 1980, pp485.

[31] ter Maat H.J., *Ibid,* pp533

[32] Kawaguchi T., *Ibid,* pp553.

[33] Raghunath T., Proc. *National Convention on Computerisation and Automation in Steel Industry,* Computer Society of India, Ranchi, 1996, pp254.

[34] Schramm R., and Kilngenberg R., Proc. *National Convention on Computerisation and Automation in Steel Industry,* Computer Society of

India, Ranchi, 1996, pp.24.

[35] Gaskin E.S., *Proc. 3rd IFAC Symposium,* Montreal, August 1980, pp627.

[36] Doi, K., *et.al., Proc. 4th IFAC Symposium Helsinki,* Finland, (August 1983) pp39.

[37] Nose K., Takemura M and Morita T., *ibid,* pp47.

[38] Prasad Rao, C.H., *Proc. National Convention on Computerisation and Automation in Steel Industry,* Computer Society of India, Ranchi, 1996, pp90.

[39] *Report No. R&D: 67:13:1629:91,* R&D Centre, Steel Authority of India Ltd., Ranchi, 1991.

[40] *Report No. R&D: 67:13:1829:92,* R&D Centre, Steel Authority of India Ltd., Ranchi, 1992.

[41] Gupta V.K., Litvinenko, V.A. and Santra, A.K., *Steel India,* 15-1, 1992, pp22.

[42] *Report No. R&D: 31:17:2340:06:94,* R&D Centre, Steel Authority of India Ltd., Ranchi, 1991.

[43] Gupta V.K. and Shukla R., *Steel India,* 17-1, 1994, pp21.

[44] Gupta V.K. Santra A.K. and Shukla R., *Steel India,* 18-1.1995, pp21.

[45] Prasad A., Deogharia S.K. and Gupta V.K. *Steel India,* 14-2 1991. pp71.

[46] *Report No. R&D: 67:02:2033:93,* R&D Centre, Steel Authority of India Ltd., Ranchi, 1992.

[47] *Report No. R&D: 67:02:1691:91,* R&D Centre, Steel Authority of India Ltd., Ranchi, 1991.

[48] *Report No. R&D: 67:02:1881:92,* R&D Centre, Steel Authority of India Ltd., Ranchi, 1992.

[49] Kumar S. *et.al., Trans. Indian Inst. Met.,* 43-5 (1990) pp.268.

[50] Barker H.A., *et.al., Proc. IFAC 10th Triennial World Congress,* Munich, FRG, Vol. 7 (1987) pp239.