Optimization of Material Procurement Plan – A Database Oriented Decision Support System

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Abstract - ***Recently, the business in steel has undergone a sea change. Customer requirements for steel products have become increasingly demanding in terms of better quality and specification. Globalization has thrown open the market to intense competition. The rise in raw material cost has put pressure on steel industry to optimize the procurement strategy time to time. It has become imperative to re-look at the production strategies and production costs to work out methods to address the market situations in a dynamic manner. Minimization of the production cost in a Blast Furnace (BF) in an integrated steel plant is a complex problem as it associates the quality, quantity, cost & freight of raw materials along with the production targets and present operating regimes. Coal forms a major source of cost in the entire gamut of Iron & Steel production. Coal quality has a direct bearing on the BF productivity and the final cost of hot metal. Steel Plants procure coal based on the quality requirements, coal availability and linkages with coal sources. This paper is based on application software that deals with the procurement of coal based on optimization techniques integrated with heuristic and statistical models.***
The software has been developed using C programming language, Oracle Developer tools as front end and oracle database as backend. This is an excellent tool for finalizing coal procurement plan, with a view to minimize hot metal cost and achieve desired coke quality at minimum cost. The software can be also be utilized for assessing the effect of Rupee / Dollar parity, effect of quality of any individual coal etc. on coal procurement plan and hot metal cost.

Index Terms - ***BF: Blast Furnace, M10: Micum 10 index, DSS: Decision Support System***

1. INTRODUCTION

Hot metal production process in an integrated steel plant is shown in Fig. 1. Coke made from coal blend at coke oven, iron ore, sinter and other burden materials are used in blast furnace for production of hot metal. Coke is the most important raw material fed into the blast furnace in terms of its effect on blast furnace operation and hot metal quality. It is well known that use of superior quality coke in blast furnace results in improvements in productivity and coke rate. Coke is produced from coal which is procured from different indigenous sources as well as sources abroad. These coals have different qualities like ash, volatile materials etc.

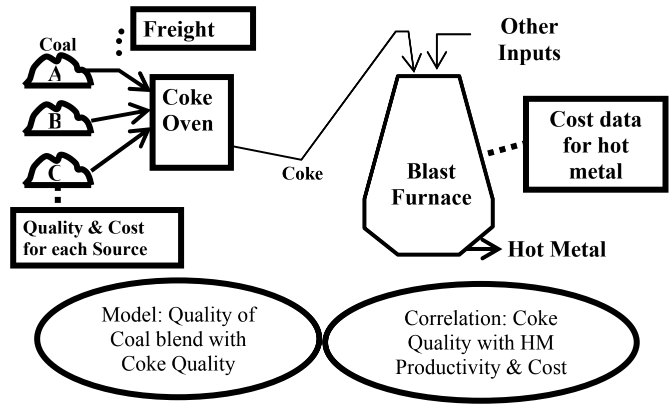

Figure1: Schematic of hot metal production process

Customers today have different options for selecting the best. They are looking for cheaper steel with better quality. This necessitates the manufacturers to have production at optimum cost. Coal accounts for significant part of hot metal cost. Selection of coal for integrated steel plant is complex as it is governed by several logistics. One has to ensure lower ash content as well as the ranking of the coal suitable for bearing burden load in blast furnace operation. Most economic blend of Primary Coking Coal (PCC) and Medium Coking Coal (MCC) suitable for operation is the prime objective.
At first glance it seems that more use of cheaper coal such as indigenous coal shall be economical. However, it is not so. The developed application software helps in decision making for selecting the right combination of coals from different sources in order to minimize the hot metal production cost in a steel plant. The software simulates different operating scenarios at the plant, then weaves them to arrive at coal procurement plans and finally optimizes to get minimum cost hot metal solutions for a plant for a given range of target productions and operational constraints. This can also be used in techno-economic evaluation of new coals including imported coals.[1]
Steel producers have been using different technologies to produce iron at minimum cost by minimizing the coal procurement cost as well as by using proper blend of coals suitable for blast furnace production. The scope of this Decision Support System (DSS) software is limited only to minimum cost hot metal production. It covers the steel plant operation up to blast furnace and basically studies the effect of

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coal quality & cost on the hot metal cost. It simulates various operating scenarios to arrive at a minimum cost hot metal solution by integrating different models namely Blast Furnace model, Coal Blending model and Coal Distribution model.

2. OBJECTIVE

Optimization of raw materials procurement at corporate level for different plants from different sources is a complex one. There can be number of sources with varying qualities as well as costs and transport logistics. Supply from all of these sources may be possible to all the plants. There are various constraints that need to be addressed before finalization of any procurement plan e.g. limited supply from the source, the coal quality variation, logistics of supply and quantity required at each unit to meet its production target. Only human experience and judgment is used to arrive at a coal distribution plan in many cases now-a-days.

The development of this decision support system was done with an aim to:

1. Fairly accurately predict the input and output costs
2. Optimized coal procurement and hot metal solution
3. Provide alternative choices to help decision making

3. APPROACH

Lot of work has been done in establishing the relationships between coal parameters and coke parameters. The coke quality parameters considered are Micum 10 (M10), coke ash etc and the coal parameters considered are coal ash, volatile materials etc. Though many techniques have been tried in blast furnace, statistical techniques have been found to be more successful compared to other models for the process. This is due to the fact that blast furnace is a multi variable process such as blast temperature, blast pressure, blast volume, oxygen enrichment, steam, top temperature, top pressure, above burden temperature, charging sequence, burden and many others. Effect and relation of these variants and complexity of the process is still not well understood. [3],[4]

Standard linear programming fails to optimize a function where the parameters involved exhibit a non-linear relationship.[3] In this software a combination of process model and linear programming method has been used. The process models are basically statistical and heuristic models. The models helped in working out the minimum cost hot metal production through optimization of total coal cost. The system consists of the following main components[1]:

1. Blast Furnace Production Rule Model
2. Coal Blend Model
3. Coal Distribution Model
4. Decision Support System (DSS) Simulator & Interface

Cost of hot metal production is the sum of coke cost, blast furnace operational cost, blast furnace burden cost, fixed cost, freights, interest & depreciation and the blast furnace gas. Burden cost consists of cost of iron ore, sinter and other burden materials. The coke cost is sum of landed coal cost, fixed cost, interest & depreciation, operational cost of coke oven and the returns from the by-products. Landed coal cost in the plant is sum of two components – basic coal cost and freight charges incurred to transport the coal to plant. Coal is the major source of cost in steel plant. It is approximately 55-65% of hot metal cost.[1],[8] In case of scarcity of proper coking coal within the country, coal is imported. This involves foreign exchange component too. To solve this issue, software programs have been written and a database oriented software approach has been adopted for coal procurement from indigenous as well as imported sources for optimum solution.

3.1. Blast Furnace (BF) Production Rule Model

Coke is the major input that affects the performance of a blast furnace. It is difficult to predict the effect of coke quality on blast furnace productivity and coke rate. Based on the experience, the working rules were defined and validated by the blast furnace experts from different steel plant[2]. The working rule predicts the coke quality in terms of M10 and coke ash requirements for targeted productivity. The working rules were validated using production data. Results from working rules for blast furnace are found to be satisfactory and reliable.[1] The working rules are written in PL/SQL and the data generated is stored in Oracle[7],[9].

3.2. CAL Blend Model [3],[4],[5]

Coal blend model defines the relationship between coal quality parameters with coke quality parameters. The model considers only the measurable and regularly monitored parameters like volatile matter and ash content. It uses volatile matter (VM) and ash for coal blending while M10 and coke ash for coke property. The aim is to decide the coal blend quality parameter for specified coke quality. The program for this model has been written in C programming language. The equations are established for each steel plant separately based on the plant operating practices and the technological regimes.

3.3. COAL Distribution Model

Coal distribution model is based on the optimization program[6],[8]. It generates the minimum cost coal linkage plan subject to the desired coal blend quality. The model incorporates the various constraints as follows:

1. Coal availability
2. Coal quality
3. Coal quantity requirements
4. Coal quality requirements
5. Coal transport linkage
6. Imported coal requirement limit
7. Coal type wise requirement

The model also uses various cost parameters like basic coal cost, freight cost and rupee/dollar parity for calculating the minimum cost coal linkage plan. As per the BF model different coke quality parameters combination may give similar hot metal production. Also different coal blend may yield same coke quality. Under such situation, cases are evaluated on economic scale. This module is written in Pro*C and this is closely coupled with blast furnace and coal blend models[9].

3.4. DSS SIMULATOR AND INTERFACE

The DSS engine simulates various operation practices for a minimum cost hot metal solution by integrating the three models viz, blast furnace model, coal blending model and coal distribution model. DSS simulator provides for[1],[8]:

1. Definition of present operating scenario
2. Simulation of different operating scenarios
3. Application of blast furnace model to work out coke quality & quantity requirements
4. Application of coal blending model for blend needs
5. Integration of various cost, currency, conversion rate parameters and coal distribution model
6. Working out of a least cost solution for each scenario
7. Cost optimization for different production range

This module provides for suitable GUI (Graphics User Interface) to facilitate entry of operational base data, coal sources, constraints, cost figures for coal and other burden materials, interest depreciation, operating cost, freight charges and currency conversion rate etc[7],[8]. It also provides for interfaces to see the details of different outputs in user-friendly manner. All GUIs have been developed using Oracle Developer tools.[9]

4. SCHEME

The application software has been developed for minimization of cost of hot metal at company level through optimized procurement plan for coal. To validate the model with plant operating data, it was felt necessary to carry the optimization for one plant at a time and later on integrate for the whole company. The different inputs to this system are:

1. Present operating parameters e.g., hot metal production, productivity, coke rate, coke ash etc.
2. Blast Furnace volume, working days etc.
3. Coal source, type, quality, supply constraints, freight, cost, transportation loss, handling loss etc.
4. Blast furnace coke yield i.e., coal to coke ratio
5. Coal usage constraints by source, imported coal usage, quality constraints
6. Operational fixed costs for coke oven & blast furnace
7. Currency conversion rate

The model calculates different costs for the given range of hot metal production in small steps. It outputs the coal cost, coke cost, variable cost and total cost of production[8]. For each production level, it gives the coal procurement plan from different sources at minimum cost. Model displays different kinds of trend graphs such as hot metal productivity vs. coal cost per ton of hot metal, hot metal productivity vs. coke cost per ton of hot metal, hot metal productivity vs. variable cost per ton of hot metal, hot metal productivity vs. hot metal cost per ton etc. Subsequently one can also generate trend graphs for imported coal %age vs. coal cost / coke cost / variable cost / hot metal cost. These graphs are useful for country like India where the good quality coking coal is scarce and there is always a need to import the same.

5. RESULT & DISCUSSION

Coal accounts for significant part of hot metal cost. Selection of coal for integrated steel plant is complex as it is governed by several logistics. The most economical coal procurement plan differs with change in coal cost, transportation cost as well as the currency conversion rate. Considering all these factors, decision making for the best option is tough.

Trials were conducted with real life data for Bhilai Steel Plant, SAIL. The simulation model revealed that minimum hot metal cost/ton was achieved at x_1 level of productivity corresponding to x_1' % of imported coal. Coal from captive mines of SAIL was shown to be used to its maximum capacity at the minimum hot metal cost/ton. Model indicated higher use of imported coal will lead to higher level of productivity but hot metal cost/ton will shoot up. This was on account of coal from captive mines getting replaced by imported coal. The cost difference between the two was quite high.[8]

6. CONCLUSION

The developed software is an excellent tool for finalizing coal procurement plan with a view to minimize hot metal cost and achieve desired coke quality at minimum cost. It can also be utilized for assessing the effect of Rupee/Dollar parity, quality of individual coal on coal procurement plan and hot metal cost.

FUTURE SCOPE

Coal Blending and Blast Furnace models can be further refined. Rule based part of the model may be replaced by the equations governing the process. The system can be used in any steel industry with tuning of model parameters used as per the plant practices.

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TABLE II Comparison of factors of attrition with nature of work group
W1 – Medical Professionals W2- Nurses and Paramedics W3 – Administrators = DUNCAN'S MEAN TEST

Factors of Attrition	W1		W2		W3		W1 V/s W2	W1 V/s W3	W2 V/s W3	F- Value
	Mean	SD	Mean	SD	Mean	SD				
Compensation and Perks	2.88	.84	3.03	.71	2.53	.80	-	*	*	11.52**
Work life balance	2.65	.78	2.80	.55	2.44	.70	-	*	*	7.77**
Sense of accomplishment	2.67	.49	2.77	.49	2.6	.55	-	-	*	3.39**
Work load leading to exhaustion	2.88	.81	2.94	.74	2.9	.84	-	-	-	.24
Need for Automation and technology improvement	2.17	.73	2.40	.72	2.17	.69	*	-	*	4.24**
Break Monotony of Work	2.94	.83	2.92	.51	2.92	.62	-	-	-	.03

NS : Not Significant * Significant at 0.05 level ** Significant at 0.01 leve

TABLE VII Comparison of factors of attrition with Income group
I I1 = UPTO RS.10,000/- , I2 = RS.11 – 20,000/- , I 3 = RS21 – 30,000/-, I 4 = RS.31 – 40,000/-, I 5 = MORE THAN RS.40,000/-) - DUNCAN'S MEAN TEST

Factors of Attrition	I1		I2		I3		I4		I5		compare	F - Value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Compensation and Perks	3.00	.69	2.87	.88	2.61	.85	2.99	.77	2.9	.73	I2 Vs I3 I3Vs I5 I3 Vs I4 I1 Vs I3	3.45**
Work life balance	2.73	.47	2.66	.68	2.57	.80	2.79	.75	2.57	.67	-	1.49
Sense of accomplishment	2.81	.51	2.68	.50	2.65	.56	2.83	.49	2.50	.38	I1 Vs I5 I3 Vs I4	4.93**
Work load leading to exhaustion	3.01	.69	2.95	.77	2.74	.72	2.95	.82	2.95	.97	I1 Vs I3	1.57**
Need for Automation and technology improvement	2.47	.78	2.39	.63	2.18	.75	2.24	.69	1.98	.65	I4 Vs I5 I2 Vs I5 I1 Vs I5 I1 Vs I3	5.29**
Break Monotony of Work	3.02	.43	3.02	.63	2.97	.75	2.73	.73	2.85	.76	I3 Vs I4 I2 Vs I4 I1 Vs I4	2.33**

lNS : Not Significant * Significant at 0.05 level ** Significant at 0.01 level